As practised by 1. Buck Bros. 2. The Miller Bros. Cutlery Co. 3. Brown & Sharpe M'f'g Co. 4. Morse Twist Drill Co. 5. The Pratt & Whitney Co. 6. J. A. Fay & Co. 7. Hoopes & Townsend. 8. Freeland Tool Works. 9. Joshua Oldham. 10 R. Hoe & Co.

Patented July 2, 1878.

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APPLETONS'

CYCLOPÆDIA OF APPLIED MECHANICS:

A DICTIONARY

OF

Mechanical Engineering and the Mechanical Arts.

ILLUSTRATED WITH

NEARLY FIVE THOUSAND ENGRAVINGS.

EDITED BY

PARK BENJAMIN, PH. D., LL. B.

IN TWO VOLUMES.

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1891.

CYCLOPÆDIA

OF

APPLIED MECHANICS.

GEARING. Wheel-work in which motion is transmitted from one wheel to another by means of teeth upon their peripheries, is called gearing. The axes of a pair of wheels in gear may have different relative positions, and the teeth may act upon each other in different ways. There are in consequence six varieties or classes of gearing, viz.: 1, spur-gearing; 2, bevel-gearing; 3, skew-gearing; 4, screw-gearing; 5, twisted gearing; 6, face-gearing.

In general, if the teeth of wheels in gear be indefinitely increased in number and reduced in size, they will ultimately become mere lines, or elements of surfaces in contact. These are called the pitch-surfaces; their relative motions are the same as those of the wheels from which they are thus derived, and their forms and disposition depend upon the class of gearing to which those wheels originally belonged. In spur, bevel, and skew gearing, the surfaces of the teeth are composed of right lines; two engaging teeth of a pair of either kind of wheels touch each other along a right line, and

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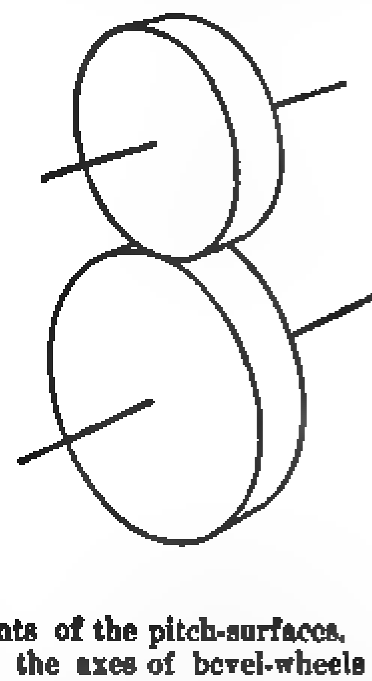
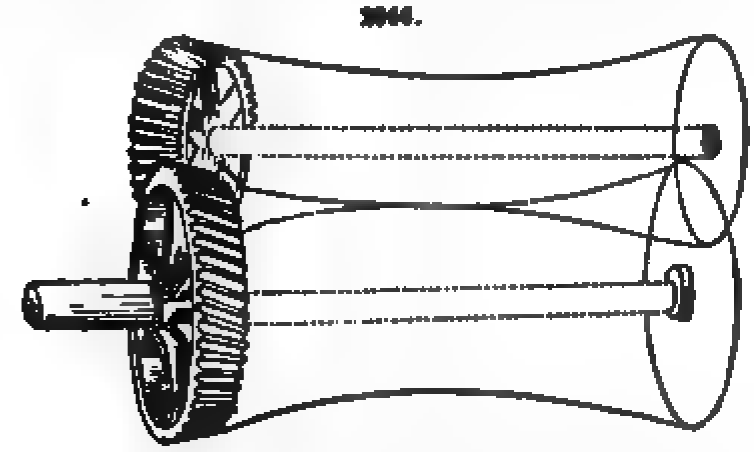


the teeth are by the above process reduced to *rectilinear* elements of the pitch-surfaces. The axes of spur-wheels are parallel, and the pitch-surfaces are cylinders; the axes of bevel-wheels intersect, and the pitch-surfaces are cones whose common vertex is the point of intersection; the axes of skew-wheels lie in different planes, and the pitch-surfaces are hyperboloids. In all these cases the pitch-surfaces are tangent along an element; but in screw-gearing the teeth are of helicoidal form, and ultimately become *helical* elements of cylinders which, since the axes are not in the same plane, are tangent to each other at a single point only. It is this fact which most strikingly marks the distinction between screw and twisted gearing, which are sometimes confounded with each other. But in the latter the axes are in the same plane, and the teeth, of helicoidal form, finally reduce to cylindrical helices or conical helices upon pitch-surfaces which are tangent along an element. There is no screw-like action of one wheel upon the other, as there is in screw-gearing, and twisted wheels are in fact only modified forms of spur or of bevel wheels. In the explanation of their construction

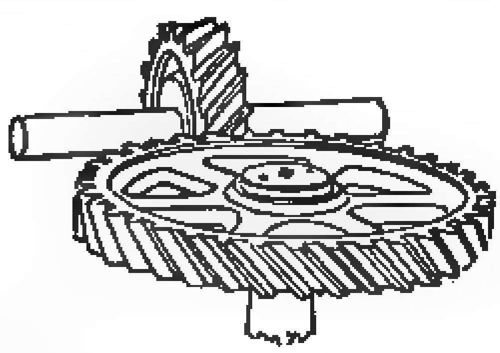
they will accordingly be treated as such, although the peculiar conformation of the teeth has caused them to be placed in a distinct class.

These five varieties are those most extensively used in modern machinery, and the general appearance of a pair of wheels and their pitch-surfaces, of each class, is shown in Figs. 2064 to 2068. Face-gearing is now rarely met with; the name is derived from the fact that the wheels were usually formed with teeth consisting of turned pins projecting from the faces of circular disks, as shown in Fig. 2069; a mode of construction well adapted to wooden mill

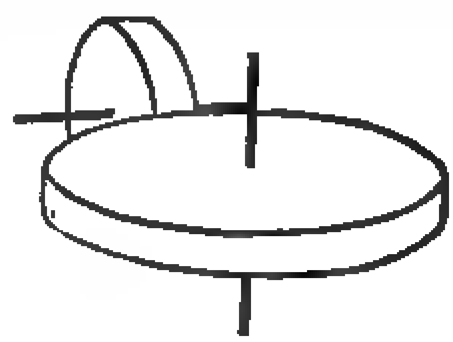
2066.



work, and to that only. In the case illustrated here, these pins, by indefinite increase in number and diminution in size, will finally become *points* in the circumferences of circles which roll in contact. These axes are perpendicular to each other, but turned pins may be inserted in other surfaces than planes, and in this way such wheels can be made to work together when the axes have other relative positions than the one here shown. All these may be properly said to belong to the same class, the characteristics being that, whatever the relation of the axes or the general form of the wheels, the teeth are circular in their transverse sections, touch each other in a single point, and ultimately become points, the



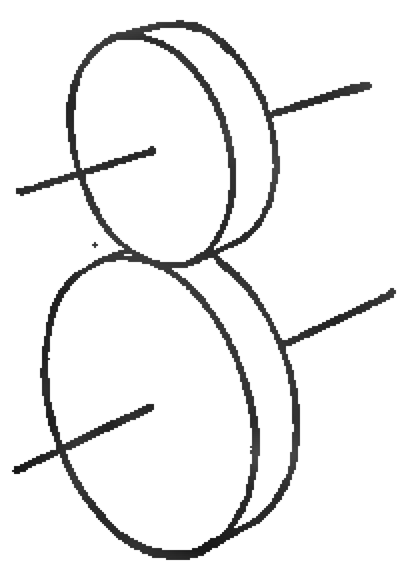
2067.



wheels having no pitch-surfaces properly so called, although in constructing them surfaces of some kind must be provided in which to secure the teeth.

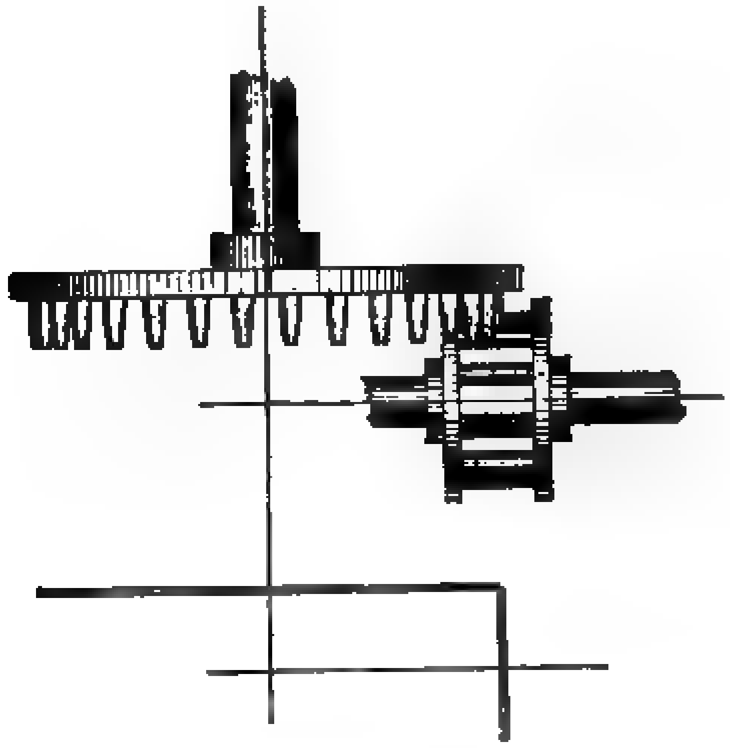
The following table exhibits in a manner convenient for reference the peculiar features of the different kinds of gearing above mentioned. The teeth, the forms of whose linear elements are given in the last column, are supposed to be of sensible magnitude, in order that the circular sections of

2068.



those in the last class may be kept in view. For in face-gearing the increase in the number involves a diminution in the length as well as in the diameter of the teeth, so that at the limit they vanish

2069.



2070.

altogether, as just explained; whereas in the other classes the length of the teeth is not affected by any variation in the height or thickness, and they reduce to lines.

CLASS OF GEARING.	Relative Position of Axes.	Pitch-Surfaces.	Elements of Teeth.
1. Spur.....	Parallel	Cylinders.....	Rectilinear.
	In same plane.		
2. Bevel....	Intersecting..............	Cones.........	
3. Skew....	....	Hyperboloids.	
	In different planes.		
4. Screw....	....	Cylinders.....	Helical.
5. Twisted..	Parallel............	Cylinders	
	In same plane.	or	
	Intersecting.......	Cones	
6. Face.....	Indifferent...............	None.	Circular.

Principles of Forms of Gear-Wheels.—The proper action of gear-wheels of any kind evidently depends upon the forms of the teeth. In order to proceed intelligently in determining these forms, a clear understanding of the principles involved is necessary; which can be most readily gained by first considering two pieces rotating in contact about fixed parallel axes.

In Fig. 2070, let C and D be the centres of motion of the two curves in contact at P; then, if the upper one turn as shown by the arrow, it will drive the lower one before it. Since the point P of the upper curve moves in a circle about D, the direction of that motion at the instant is perpendicular to $D\,P$, the contact radius, and its linear velocity may be represented by $P\,E$. Through P draw $T\,T$ the common tangent of the curves, and $N\,N$ their common normal: then $P\,E$ may be resolved into the components $P\,B$, $P\,A$. Of these the former is ineffective, as, if P moved in the direction of the tangent, it would merely slide upon the lower curve. But the normal component $P\,A$ compels the lower curve to rotate around C. The motion of P considered as a point in this curve will therefore be perpendicular to $C\,P$; and the magnitude $P\,F$ of this resultant must be such that its normal component shall also be $P\,A$: for if this component were greater, the curves would not remain in contact, and if less, they would intersect. Now draw $D\,H$ perpendicular to $N\,N$, thus making the triangle $D\,H\,P$ similar to $E\,A\,P$; draw $C\,G$ perpendicular to $N\,N$, making $C\,G\,P$ similar to $A\,P\,F$; also $C\,D$ cutting $N\,N$ in I, and making $C\,G\,I$ similar to $H\,D\,I$.

Let v = angular velocity of upper curve around D.
" v' = " " of lower " " C.

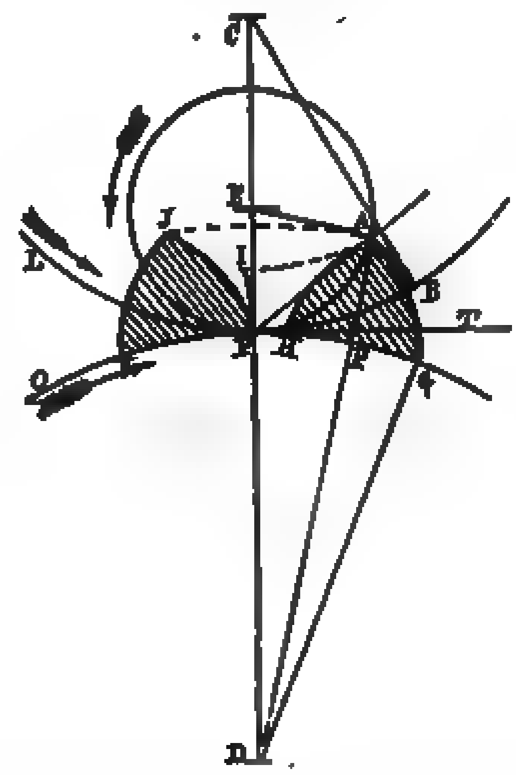
Then, since angular velocity $= \dfrac{\text{linear velocity}}{\text{radius}}$, we shall have

$$\left.\begin{aligned} v &= \frac{P\,E}{P\,D} = \frac{P\,A}{D\,H}, \\ v' &= \frac{P\,F}{P\,C} = \frac{P\,A}{C\,G}, \end{aligned}\right\} \therefore \frac{v}{v'} = \frac{C\,G}{D\,H} = \frac{C\,I}{D\,I}$$

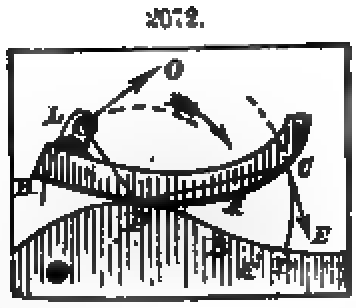
That is to say, the angular velocities are to each other inversely as the perpendiculars from the centres of motion upon the common normal; or, inversely as the segments into which the common normal cuts the line of centres. And if it be required that the velocity ratio shall remain constant, it follows that *the common normal must always cut the line of centres in the same point.*

Now, PB represents the sliding of the driver, PO that of the follower, upon the common tangent; therefore OB, their difference in this instance, represents the sliding of one piece upon the other. Had O and B fallen on opposite sides of NN, this sliding would have been $PO + PB$. But it is clear that there will always be a sliding of one upon the other, unless the tangential components have the same magnitude and direction. And as the normal component is the same for both rotations, this can happen only when the resultants PE and PF coincide; in which case the contact-radii DP and CP, to which those resultants are respectively perpendicular, must also coincide in one right line, that is, in the line of centres. In other words, *pure rolling contact can exist only when the point of tangency is on the line of centres*, as in Fig. 2071. Since P and I here fall together, and the linear motions are identical, we see at once that the angular velocities are inversely as the contact-radii. And because, if the velocity ratio is to be also constant, these contact-radii must remain constant, it follows that *the only curves which can move in rolling contact with a constant velocity ratio are two circles*, whose centres are C and D, portions of which are shown in dotted lines in the figure. These circles may be regarded as cut from the pitch-cylinders of a pair of spur-wheels by the plane of the paper, supposed to be perpendicular to the axes. Now the linear motion of the point P in the driver, coinciding with the tangent, has no normal component, and therefore no tendency to compel rotation

2071.



2072.



of the follower; which agrees with the well-known fact that two perfectly smooth cylinders will merely slip upon each other. Compulsory rotation then requires the addition of teeth to circular wheels; and if in Fig. 2070 we also regard the circles drawn through I as the sections of pitch-cylinders, it will be clear that the contact-curves shown in that figure will fulfill the functions of teeth if they be of such form that their common normal shall always pass through I.

The principle upon which the finding of such curves depends is illustrated in Fig. 2072. A piece with a curved edge, PBD, is fixed upon a plane surface; and HAC is a loose curved ruler which may roll upon it. The two curves are now in contact at P: let the upper one roll to the right as shown by the arrow; which means that each point in its order of the one shall come into contact with each point in its order of the other. Thus, PA is equal to PB, and A will come into contact with B; PAC is equal to PBD, and C will come into contact with D. At the present instant P is the centre upon which the upper curve is turning. Every point in it or rigidly connected with it is therefore moving in a circular arc of which P is the centre. Thus the motion of C is at the instant in the direction CE, tangent to that arc, or perpendicular to CP. CE is therefore tangent to the curve CD, which will be traced on the plane to which PBD is fastened, and CP is normal to it. The point C is on the rolling curve; but this is not necessary. A marking-point, for instance, may be placed at L; and it is at the instant moving in the direction LO, perpendicular to LP, and LO would be tangent to the curve traced by L upon the plane. At the next instant the point of contact will change, but that point is always the centre about which the rolling curve is turning. Thus when A reaches the fixed curve at the point B, the latter will be the instantaneous axis. It is not necessary that PBD should be fixed: we may suppose the upper curve to be fixed, and the lower one to roll upon it, carrying the attached plane under the tracing-point C; or both may be in actual motion, provided that the relative motions are such that the one measures itself off upon the other. The principle is that, if one curve move in rolling contact with another, the point of contact is the instantaneous axis, through which passes the normal to any line traced by a point connected with one upon the plane of the other.

SPUR-GEARING.

The application of the above principles to the construction of the teeth of spur-wheels is shown in Fig. 2073. Let C D be the axes, perpendicular to the paper, and $L P B$, $O P G$, parts of the *pitch-circles*, or sections of the pitch-cylinders, in contact at P. Let E be the centre of another circle tangent also at P to the other two, and carrying at P a marking-point. Let these three circles roll in contact as shown by the arrows, with the same linear velocity. Then, while the lower pitch-circle turns through the angle $P D G$, the upper one will turn through the angle $P C B$, and the describing circle through the angle $P E A$, the arcs $P G$, $P B$, and $P A$ being equal; and meantime the marking-point will have traced the curves $G A$, $B A$ on the planes of the lower and upper pitch-circles respectively. Evidently, $A G$ is the *epicycloid* formed by rolling the describing circle on the outside of the lower pitch-circle, and $A B$ is the *hypocycloid* generated by rolling the same describing circle on the inside of the upper pitch-circle. And from what precedes it is clear that these curves will act together properly as parts of the outlines of teeth. $P J$, $P I$ represent the same curves in contact at P; and the wheel D being turned to the right, $P J$ will drive $P I$ before it, the point of contact being on the arc $P A$, the common normal passing always through P, and the velocity ratio being constant, until J and I come together at A. Here the action ends, and, the rotation being kept up by other teeth, this pair of curves quit contact. While it is not necessary that a circle should be taken as the describing curve, it is more convenient in practice; and the teeth whose forms are thus determined, known as *epicycloidal*, are those most extensively employed. The curve $A G$, which lies without the pitch-circle of its wheel, is technically called the *face* of the tooth; and the curve $A B$, lying within the pitch-circle, is called the *flank* of the tooth to which it belongs. Usually the teeth of each wheel have both faces and flanks; but as continuous rotation can be and sometimes is kept up without the aid of other curves than those shown, we will first consider the conditions under which this is possible.

The arc of the pitch-circle occupied by a tooth and a space is called the *pitch* of the teeth; and a fractional tooth being impossible, the pitch must be an aliquot part of the circumference. If two wheels gear together, the pitch must be the same in each, so that the numbers of the teeth must have the same ratio as the diameters of the pitch-circles. The problem usually presented in practice is, to construct a pair of wheels which shall work with a given velocity ratio upon axes also given in position. The distance between the centres, being thus known, is divided into segments having the given ratio, and the pitch-circles, described with these segments as radii, are divided into as many equal parts as it is proposed to have teeth. The pitch, being thus found, is again divided into two parts, one being the thickness of the tooth, the other the breadth of a space. If absolutely accurate workmanship were possible, these parts might be exactly equal; but as it is not, the space must in practice be a little greater. The difference is called *backlash:* if the wheels are to be cast merely, it is customary to make this a certain fraction (from $\frac{1}{15}$ to $\frac{1}{11}$) of the pitch; but in cut gearing of any pretensions to accuracy, there is no reason why it should be anything like so large, or why it should vary with the pitch; it should be as small as the skill of the workman can make it with the tools at command.

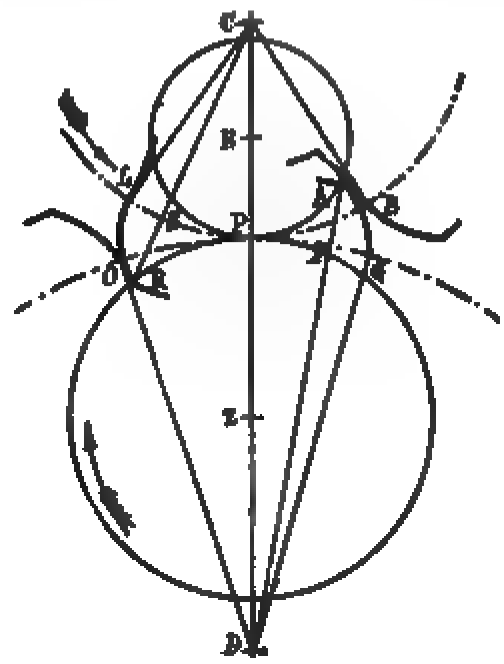
Now, referring again to Fig. 2073, let us suppose that $P G$ had been determined as the pitch, and $G H$ as the thickness of a tooth, on the wheel D. Having selected a describing circle and constructed the curve $G A$, the tooth is then to be completed by drawing the similar but reversed curve $H A$. This diagram is so proportioned that these curves intersect at A, and we see that this is the limiting case; the angle of action $P D G$ is equal to the pitch, and it cannot be made less, or one tooth would cease to act before the next one began. This determines the necessary length of the face $A G$; and since the opposite face also passes through A, it is just possible to make the tooth, which in this case is pointed, of the requisite length. In this case also the line $A D$ bisects $G H$, and is the radius of symmetry. But if, after determining A, the arc $G H$ had been so cut by $A D$ that $G F$ were less than $F H$, the tooth might have been made longer by continuing both faces, thus increasing the angle of action, or it would be of some thickness at the top, as in the next figure; but if $G F$ had been greater than $F H$, the construction would have been impossible, the two faces intersecting below the point A. Now it is clear that a limiting case like this cannot be safely adopted in practice; the least inaccuracy in workmanship, or a very little wear (to which pointed teeth of this form are especially liable), will reduce the angle of action, and cause one tooth to quit correct driving contact before the next one begins to act. We say *correct driving contact:* if in Fig. 2073 we remove the second tooth $P J K$, the face $A G$ of the first one will push the flank $A B$ out of its way, and so turn the upper wheel; but the acting curves will not be tangent to each other, nor will the velocity ratio be constant, but the speed of C will diminish. Each tooth should therefore come into action before the preceding one goes out; that is, the arc of action $P G$ should be greater than the pitch, as in Fig. 2074, which illustrates a case practically feasible.

The construction is as follows: Having set off from P the equal arcs of action $P G$, $P B$, greater than the pitch, and selected the describing circle, we construct the epicycloidal face $G A$ and the hypocycloidal flank $B A$. Drawing $A D$, it cuts the lower pitch-circle in F, and we find $G F$ to be less than half the thickness of the tooth $G H$, so that, drawing the reversed face through H, the tooth is not pointed, but "topped off" by the circle $V A W$. The pitch-circles having been previously divided, starting at the points G, B, the other teeth of the lower wheel are drawn in their proper positions, the spaces between them being bounded not by the pitch-circle, but by a circle a little inside of it, giving a little *clearance* for the tops of the teeth on the upper wheel, the faces $A G$, etc., being continued within the pitch-circle by tangent radii. Now, as to the tooth of the upper wheel, $B A$ is the whole of the *acting* flank; but the space must clearly be made considerably deeper, to allow the passage of the tooth of the lower wheel. The exact form of this space is immaterial, so long as the space is great enough; but it is usual to extend the hypocycloid $B A$ to S as shown, the bottoms of the spaces being formed by a circle whose centre is C, which allows also a

clearance between it and the tops of the engaging teeth. When it is possible to construct wheels in this way, they will fulfill perfectly the requirement of transmitting continuous rotation with a constant velocity ratio. But if the wheel C, for example, be very small in proportion to D, the teeth of the latter will require to be very long, and in many if not most cases this construction will be impossible; and in many cases it is not desirable even when possible, for a reason which will appear from the following considerations: If we suppose D to be the driver, and to turn to the right, the action begins at P and ends at A, the point of contact continually receding from the line of centres. But if we suppose C to drive in the opposite direction, the action begins at A and ends at P, and the point of contact is continually approaching the line of centres. There is during the action an amount of sliding equal to the difference between the lengths of the acting curves $A\,G$, $A\,B$; and it has been found that the friction is greater and more injurious in the latter case than in the former, the difference being analogous to that between pushing and drawing a cane over a pavement to which it is inclined. Of such a pair of wheels, then, the one whose teeth have *faces* ought always to drive, and the one with *flanks* only ought always to be the follower. But in many cases a wheel must be turned by another, and also drive a third. And besides, it is to be noted that the longer the face of the tooth, the greater is the angle between the line of action $P\,A$, Fig. 2073, and the common tangent of the pitch-circles $P\,T$. The pressure as well as the motion acts in this line; and the greater this obliquity, the greater will be the component in the line $C\,D$, that is, the greater will be the

2074.

2075.



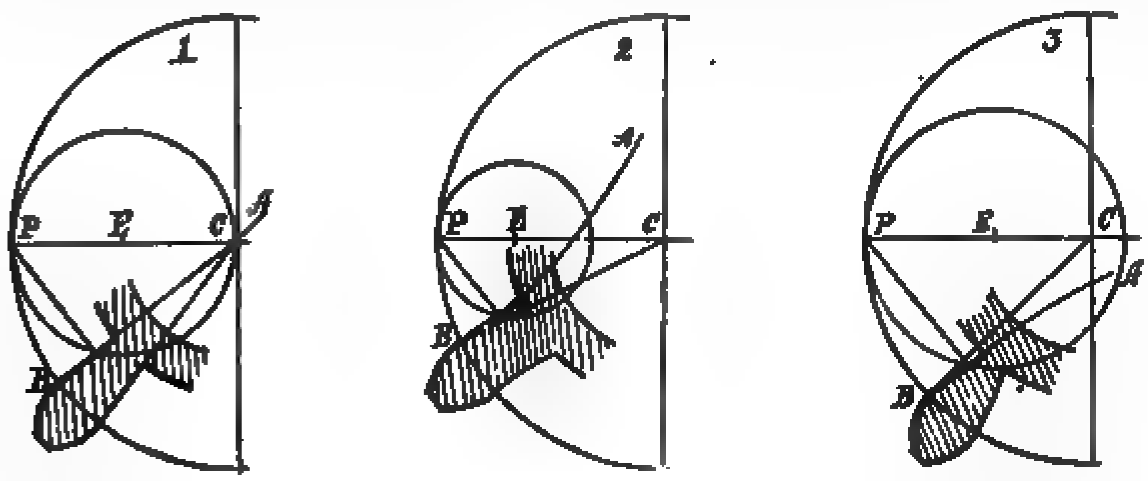
2076.

pressure on the journals. And finally, the difference between the lengths of the face and the flank which act together, and therefore the sliding, increases more and more rapidly as we recede from the pitch-circles. This latter fact is sufficient to show that the teeth of wheels ought always to be as small and numerous as possible; though this is in many cases also affected by considerations relating to the pressure to be transmitted and the strength of the materials to be used, with which we have nothing to do.

It will now readily be seen, that by using another describing circle on the other side of the point P, as in Fig. 2075, thus giving both faces and flanks to the teeth of each wheel, two things will be accomplished: a given angle of action may be secured with shorter faces and therefore less sliding, and this angle will be divided into an angle of *approaching* and an angle of *receding* action, thus enabling us to use either wheel as the driver. If a wheel has both to drive and to follow, it may be well to subdivide the angle of action equally; but in case it is to act as a driver only, its *arc of approach* may advantageously be made less than its *arc of recess*, in order to reduce the amount of the more injurious friction. The diameters of the pitch-circles and the numbers of the teeth being given, the pitch is determined, and, making the allowance for backlash, we find the thickness of the tooth. If we then assume the arcs of approach and of recess, we can determine whether the proposed conditions can be satisfied, and if so, the forms of the teeth as well as their heights, by constructing the diagram, Fig. 2075, thus: Let D be the driver, and $P\,O$ its arc of approach, which is

equal to $P\,L$, that of the follower. Taking any point Z on $D\,P$ as the centre of a describing circle, draw the epicycloid $L\,R$ by rolling it on the outside of $L\,P\,B$, and the hypocycloid $O\,R$ by rolling it within $O\,P\,G$. These curves are respectively the face of the follower's tooth and the flank of the driver's. Draw the radius $R\,C$, cutting the pitch-circle of the follower in S: if $L\,S$ be just half the thickness of the tooth, the construction is so far possible, but the follower's teeth will be pointed; if $L\,S$ be less than that, the teeth will be "topped off," but if greater, the size of the describing circle must be increased or the arc of approach diminished. The construction of the remainder is precisely like that of Fig. 2073, above explained. We have here assumed possible conditions, and the action is readily traced. The arrows indicating the direction of the rotations, the driver's flank

2077

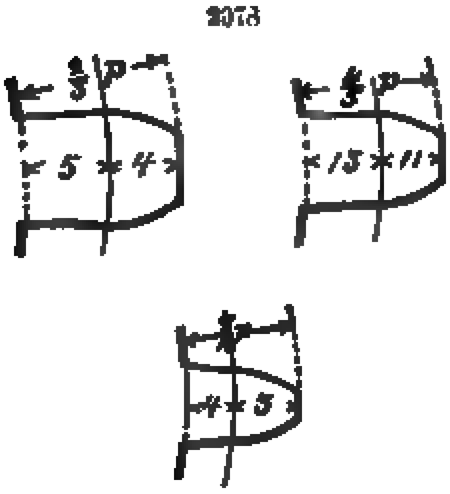


begins to act upon the face of the follower at R, and acts upon it until O and L come together at P, the point of contact lying always in the arc $R\,P$. These two curves now quit contact, and the action is continued between the face of the driver's tooth and the flank of the follower's, ending at A, as in Fig. 2073. The teeth are completed by extending the flanks, as in Fig. 2074, to form the clearing spaces, and will present the appearance shown in Fig. 2076.

Nothing has been said thus far about the diameter of the describing circle. In Fig. 2077 are shown three cases, this diameter being equal to, less, and greater than the radius of the pitch-circle within which the describing circle rolls. In the first case the hypocycloid $B\,A$ becomes a diameter of the pitch-circle, and the tooth, having radial flanks, is weak at the root. In the second case the flank is tangent to the radius $B\,C$ at B, and curves away from it as it recedes from the pitch-circle, giving a much stronger form of tooth, which is therefore to be preferred for heavy work. In the third case the flank is still tangent to the radius $B\,C$ at B, but curves in the opposite direction, the tooth consequently being not only weak but difficult to make. But with a given arc of action the greatest obliquity of the normal will be less, the greater the diameter of the describing circle; so that in watchwork or other delicate mechanism the third form might be employed.

It will be noted that the face and the flank, which act in contact, are generated by the same describing circle. Consequently, if it be required to make a set of wheels such that any two of them shall gear correctly together, not only must the pitch be the same in all, but the same describing circle must be used for tracing all the faces and all the flanks. And the diameter of this, for the reason just pointed out, should not be greater than the radius of the smallest wheel of the set. If it be

2078



just equal to that radius, that wheel will have teeth with radial flanks; but these may be materially strengthened by joining them to the bottoms of the clearing spaces by circular arcs, as in Fig. 2079; which indeed can be done in any case, as the depth of the space is considerably greater than the length of the *acting* flank, as shown in Fig. 2074.

From Fig. 2075 it appears that the arc of approach varies with the length of the face of the follower, the arc of recess with that of the face of the driver. If it be imperative, then, that the latter arc be the greater, the length of the face of a tooth will depend upon whether it is to drive or be driven. But in the majority of cases in ordinary practice this is not essential; and among millwrights the custom obtains of disregarding this distinction, and making the depth of the tooth, within and beyond the pitch-line, bear certain definite proportions to the pitch itself. In Fig. 2078 are shown three slightly different proportions. In the first the whole depth is two-thirds of the pitch, the part within being to that without the pitch-circle as 5 to 4; in the second the whole depth is four-fifths of the pitch, divided in the proportion of 13 to 11; and in the third we have four-tenths within and three-tenths without the pitch-circle. By adopting either of these systems of proportioning the teeth, the wheels will work together without risk of a tooth going out of gear too soon, provided that none of them have less than 15 teeth; but of course the arcs of approach and of recess will vary according to the numbers of the teeth and the size of the describing circles selected. But as the locus of contact is always the circumference of that describing circle, it is easy to determine by the diagram, Fig. 2075, what these arcs are. And as the necessary arc of action, and with it the necessary length of the face, increases with the pitch, it will be found that these proportions, though good within the limits named, will not answer if the number of teeth in a wheel be small; and the length of the tooth must be determined in such cases by actual construction, as above explained.

Rack and Wheel.—If one of a pair of wheels become infinitely large, its pitch-circle will become a right line tangent to that of the other wheel, as $O\ G$, Fig. 2079. The similarity of this diagram to Fig. 2075 is so great, that hardly any explanation is needed. The same or different describing circles, on opposite sides of the point of contact, are used for generating the acting curves, the teeth of the wheel having epicycloidal faces and hypocycloidal flanks as before, while both faces and flanks of the rack-teeth are cycloids. The arc of action $L\ P\ B$ of the wheel is of course equal to $O\ P\ G$ on the pitch-line of the rack, $L\ P$ being equal to $O\ P$, and $P\ B$ equal to $P\ G$, and the necessary lengths of the faces and flanks are determined, the teeth completed, and the clearing spaces formed exactly as in Fig. 2075; the only point of difference being, that when the pitch and the arc of action are assumed, and the necessary length of the cycloidal face $A\ G$ of the rack-tooth has been found, the possibility of satisfying the conditions is determined by drawing a perpendicular to $O\ G$ from A, cutting the pitch-line in F: if $F\ G$ be less than or equal to half the thickness of a tooth, the construction is possible; but if greater, it is not. If the describing circles E, Z be of equal diameters, and the same circle be used for the faces and flanks of a set of wheels, any one of them will gear correctly with the rack if the pitch be the same.

If, as in Fig. 2080, the upper describing circle be of half the diameter of the pitch-circle, the flanks of the wheel-teeth become radial. We may assume a similar case below; but the pitch-circle of the rack being of infinite diameter, its radius is also infinite, and the describing circle is therefore the pitch-line of the rack, which rolling on the upper pitch-circle gives involutes of that circle for the faces of the wheel-teeth. Thus, let $L\ P$, the arc of approach, be equal to $O\ P$ on the pitch-line; then, as the rotation progresses, a marking-point at O will trace on the plane of the wheel the involute $O\ L$, and on the plane of the rack the traced curve will degenerate into the point O, which will meet L at P. The action is therefore bad, the wear during approach being confined to this single point on the rack-tooth, which has no flank proper. A clearing space is however needed, and $O\ V$ may be a circular arc whose centre is P and radius $P\ O$, the radius of curvature of the involute $O\ L$ at O.

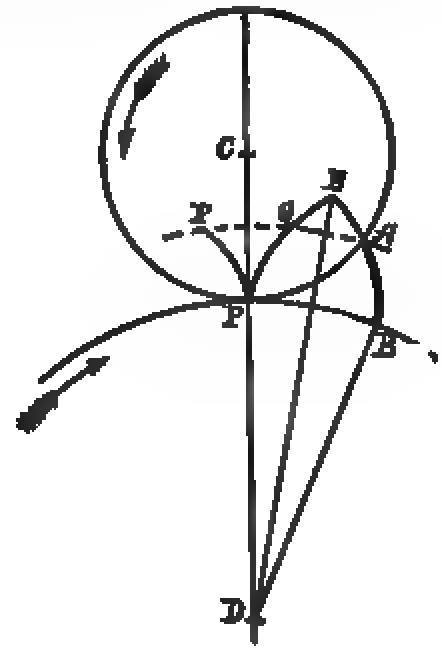
Annular Wheels.—An annular or internally-toothed wheel may either drive or be driven. The construction of the teeth in the former case is illustrated in Fig. 2081. The diameter of the describing circle E is, for reasons before explained, taken less than the radius of the smaller wheel: both the face $A\ G$ of the driver's tooth and the flank $A\ B$ of the follower's lie within the pitch-circle and are hypocycloidal. Since the pitch-circles both curve in the same direction, the teeth continue longer in gear than in the case of external contact, and it is usually unnecessary to have any arc of approach; but should it be required, it may be obtained thus: Let $P\ O$ be equal to $P\ L$; then a tracing-point fixed at O in the outer pitch-circle will mark on the plane of the inner one the internal epicycloid $O\ L$, and on its own plane merely the point O, to which therefore the action of the follower's face is confined. The possibility of satisfying the assumed conditions is determined exactly as in the cases already described. Thus, $A\ G$ is the necessary length of the driver's face, with the given describing circle and for the arc of recess $P\ G$. Draw $D\ A$ cutting the pitch circle in F; then $F\ G$ must not be greater than half the thickness of the tooth, which is known if the number of teeth be assigned. The clearing space of the follower is formed as usual by continuing the hypocycloidal flank to the requisite depth; in the annular wheel a short radial line, tangent to the face $A\ G$ at G, is drawn to limit this space on the side, the bottom being a circle whose centre is D. In both wheels the corners of the spaces may be rounded. Now it will be seen that if the pinion drive, the action will be confined to the arc of recess by cutting down the faces of the teeth of the wheel to the pitch-line; and by reducing their length to a less extent, and increasing the face of the pinion's tooth, the action may be divided in any desired proportion. In all cases, however, it is better to have no arc of approach if it can be avoided without unduly lengthening the face of the driving tooth, which increases the obliquity of the line of action and also the sliding. But we have also just seen that the action of the curve $O\ L$ is confined to the single point O on the outer wheel; and this is a serious objection to the method above mentioned of forming the teeth when the pinion is to drive.

A much better way is shown in Fig. 2082, a describing circle E being used whose diameter is equal to or greater than the radius of the annular wheel, and always greater than the diameter of the pinion. The hypocycloidal face of the wheel-tooth will therefore either be a radius, or, as in the figure,

a line curving away from the radius $D\,G$; and the pinion-tooth is also a *face* instead of a flank, as it lies without its pitch-circle. The sides of the clearing spaces in the wheel and the pinion may be any circular arcs tangent to the radii at their extremities, and of less curvature than the faces $A\,B$, $A\,G$ respectively. It will be noted that in this construction it will in many cases be possible, as in

2060.

2063.

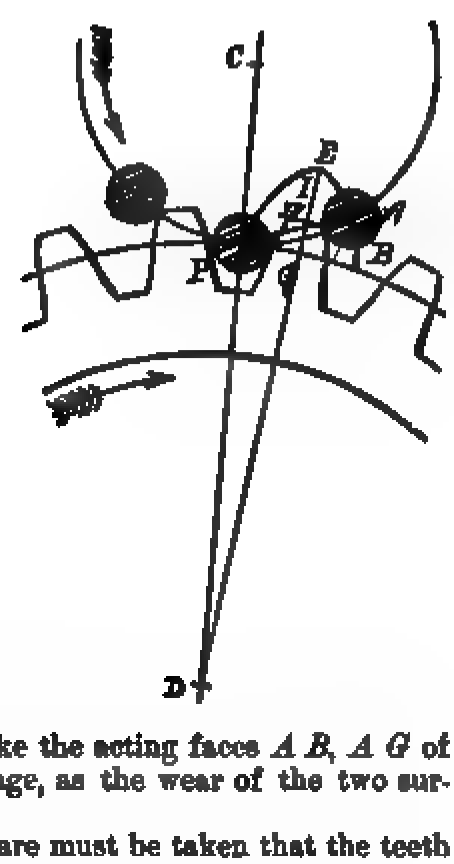


2061.

2064.

2065.

2062.



the figure, by taking the describing circle of proper diameter, to make the acting faces $A\,B$, $A\,G$ of very nearly equal length. When this can be done, it is an advantage, as the wear of the two surfaces will then be the same.

In laying out annular gearing, when the internal wheel is large, care must be taken that the teeth are not too long to clear each other; which may require attention to the following consideration: If

in Fig. 2082 we roll the pinion round within the wheel, the point A of the pinion-tooth will trace an epitrochoid on the plane of the outer wheel, which may be readily constructed, and obviously must clear the points of the teeth of the annular wheel. Similarly the highest point of the tooth of that wheel, in rolling round the pinion, will trace on the plane of the latter an epitrochoid, which must clear the points of the teeth of the pinion.

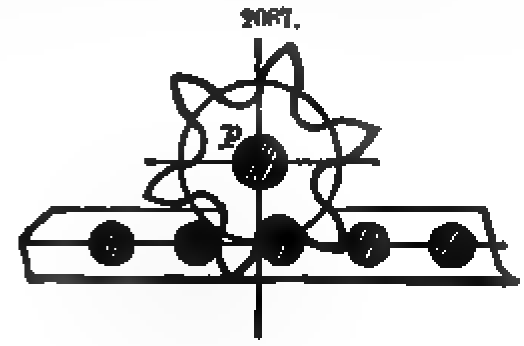
Pin-Wheels or Trundles.—A modification of epicycloidal gearing is shown in Fig. 2083. Let a marking-point be fixed at P in the upper pitch-circle; then it will trace upon the plane of the lower one, while the latter turns through the angle $P D B$, the curve $B A$, the arcs $P B$, $P A$ being equal. This curve is simply the epicycloid generated by rolling the upper pitch-circle on the lower; the curve traced on the plane of the upper degenerates into a point. $P F$ is a curve similar and equal to $B A$; and if we suppose P to be a pin of no sensible diameter, fixed in the wheel C, this curve will drive the pin as shown by the arrow, the action ending at A. Now if $P B$ be the pitch, we can construct the elementary tooth by drawing the reverse faces $B A E$, $P G E$, which will drive the pins in either direction. These faces intersect in E, thus limiting the height of the tooth when the pitch is assumed. In the diagram E falls within the pitch-circle of the upper wheel, and the face of the tooth may be made longer than $B A$, thus making the arc of action greater than the pitch: had E fallen on the circumference of C, we should have had the limiting case, the action on one pin continuing barely long enough for that on the next to begin.

Practically, the pins must have a sensible diameter, and are made cylindrical, being technically called staves, which are usually inserted into two circular disks fixed on the axis, thus forming what in mill-work is called a trundle or lantern. The form of the tooth of the wheel is derived from the epicycloid, by drawing a curve at a constant normal distance from it; which is done graphically by describing any number of circular arcs with a radius equal to that of the pin, the centres being on the epicycloid, and making the new curve tangent to them all, as in Fig. 2084.

When the number of teeth, or in other words the pitch, is assigned, it is necessary to ascertain what diameter can be given to the pins. This is done as in Fig. 2085, thus: Let $P B$ be the pitch on the driver D, $P A$ that on the follower C; draw $P A$, bisect $P B$ in G, and draw $D G$, producing it to cut $P A$ in H: then the pin may have any radius less than $A H$. For, drawing the elementary tooth $P E B$, we see that $P A$ is normal to the epicycloid $B A E$, to the parallel or derived curve, and to the circumference of the pin. If we assume $A H$ as the radius of the latter, it is plain that the highest point of the tooth will be H, and that it will be just quitting contact when the next one comes into action. With the smaller radius used in the figure, the derived tooth-outlines would intersect at I on the radius $D E$, and the tooth, if it were desirable to have it pointed, might be extended to that point. It is however better to have it "topped off" as shown, which may now safely be done, as the action on A is not yet ended, while the next tooth has begun to drive the pin P. In the elementary form, Fig. 2083, it is seen that the action is wholly confined to the arc of recess, if the teeth are given to the driver. When the pins are of sensible diameter, as in Fig. 2085, there is an arc of approach, but a comparatively small one; so that in practice the pins are invariably given to the follower.

In the case of the rack, then, the form is materially different if it drive from that which it has if driven. Fig. 2086 shows the construction in the former case; the elementary rack-tooth being the cycloid traced by the pitch-circle of the wheel rolling on its tangent, from which the practical tooth-outline is derived as before. In determining the radius of the pin, the line corresponding to the radius $D G$ of Fig. 2085 here becomes perpendicular to the pitch-line of the rack. If the wheel drive, the pins are given to the rack, and the elementary tooth is the involute of the pitch-circle of the

2087.



wheel. So also is the derived curve, which it is therefore unnecessary to construct. The appearance of the combination is shown in Fig. 2087, and it is open to the same objection as that mentioned in regard to the action of the faces of the wheel-teeth in Fig. 2080; that is, the whole wear is confined to a single point on each pin, so that it makes no difference whether the pin be circular or not, as it will work equally well if made with flat sides perpendicular to the pitch-line of the rack.

Annular pin-gearing also furnishes two cases differing materially in appearance. If the inner wheel be the driver, the construction is as shown in Fig. 2088, the elementary tooth $P E$ being the internal epicycloid generated by rolling the outer pitch-circle upon the inner, and the radius of the pin being determined as in Fig. 2085, the lettering corresponding throughout. If the annular wheel drive, as in Fig. 2089, the face of its elementary tooth is the hypocycloid generated by rolling the pitch-circle of the pinion within that of the outer wheel; and the general construction will be readily

seen by comparing this figure with the preceding one and with Fig. 2085. If the diameter of the inner wheel be half that of the annular one, the teeth of the latter become radii of the pitch-circle if the pin be a mathematical point; and when it is made of sensible diameter, the derived outline of each tooth of the annular wheel is a line parallel to its primitive radius. The arc of action may

2089.

in this case be made so long that three or even two pins are sufficient to drive the outer wheel continuously, the whole combination in the latter case assuming a very curious aspect, as shown in Fig. 2090; the pins turning in blocks which slide back and forth in the two slots at right angles to each other, which are the disguised teeth.

Spur-Wheels with Involute Teeth.—Next to the epicycloidal, the form of tooth most extensively

2090. 2092.

2091.

T

used is that of the involute of the circle. We have seen that any curve carrying a marking-point, and rolling in contact with both pitch-circles, may be used to generate the acting outlines of the teeth. Abstractly speaking, that is; for many curves which may be thus generated, although they

geometrically satisfy the conditions, are incapable of being practically used. Not so with the involute; but though it can be thus generated, its fitness for the purpose may be much more clearly and simply shown by deriving it in another way. Let C, D, Fig. 2091, be the centres of the pitch-circles $L\,P\,O$, $M\,P\,N$, in contact at P. Through P draw $A\,B$ oblique to $C\,D$, the line of centres, and let fall upon it the perpendiculars $C\,B$, $D\,A$, with which as radii draw the circles $B\,S\,F$, $A\,E\,R$. Suppose these circles to be disks upon which is wound an inextensible band $A\,B$, carrying a pencil at A: if the upper one be turned to the left, it will cause the lower one to turn to the right, and the pencil to travel in the line of the common tangent, as shown by the arrows; and in going from A to B, the pencil will mark upon the planes of the upper and lower wheels respectively the curves $A\,F$, $E\,B$. These are the involutes, not of the pitch-circles, but of the *base-circles* $B\,S\,F$, $A\,E\,R$, whose radii $C\,B$, $D\,A$ are to each other in the same ratio as $C\,P$, $D\,P$, the radii of the pitch-circles, by reason of the similar triangles $P\,C\,B$, $P\,D\,A$. By the mode of generation, the arcs $A\,E$, $B\,F$ are equal to $A\,P$ and therefore to each other; and the curves, being simultaneously described by a point which lies in the common tangent to the base-circles, that is to say, in the common normal to the involutes, are tangent to each other throughout the generation, and the common normal always cuts $C\,D$ at P. These curves may therefore be used as teeth for the wheels to which they respectively belong; thus, $A\,I\,G$, similar to $E\,B$, will drive $A\,J\,F$, as indicated by the arrows, with a constant velocity ratio, the locus of contact being $A\,B$. Now, because $A\,B$, the line of action, has a constant inclination to $T\,T$, the common tangent of the pitch-circles, there is always a certain fixed component of pressure in the line of centres $C\,D$. This, tending to cause wear in the bearings, is urged as an objection to this form of tooth for heavy work; to which the epicycloidal form is not open, as in that the obliquity of the common normal varies, and it is perpendicular to $C\,D$ when the point of contact reaches P. To offset this, however, this form possesses some advantages The line $A\,B$ was drawn at pleasure, and the demonstration in no wise depends upon its inclination; consequently, for the same pitch-circles an infinite number of base-circles may be used, or for the same base-circles an infinite number of pitch-circles may be assigned, the only condition being that the diameters shall have the same ratio in either case. Therefore any two wheels with involute teeth will gear together correctly if the pitch be the same in each; and further, the velocity ratio will not be affected by changing the distance between the centres, the effect of which is merely to alter the obliquity of the line of action. The backlash may therefore be reduced to a minimum by bringing the axes as close together as they can be without causing the teeth to bind; and if by wear of bearings the axes become too widely separated, the teeth will still gear correctly so long as they engage at all. None of these things can be said in favor of the epicycloidal form; and moreover, the involute is essentially a strong form of tooth.

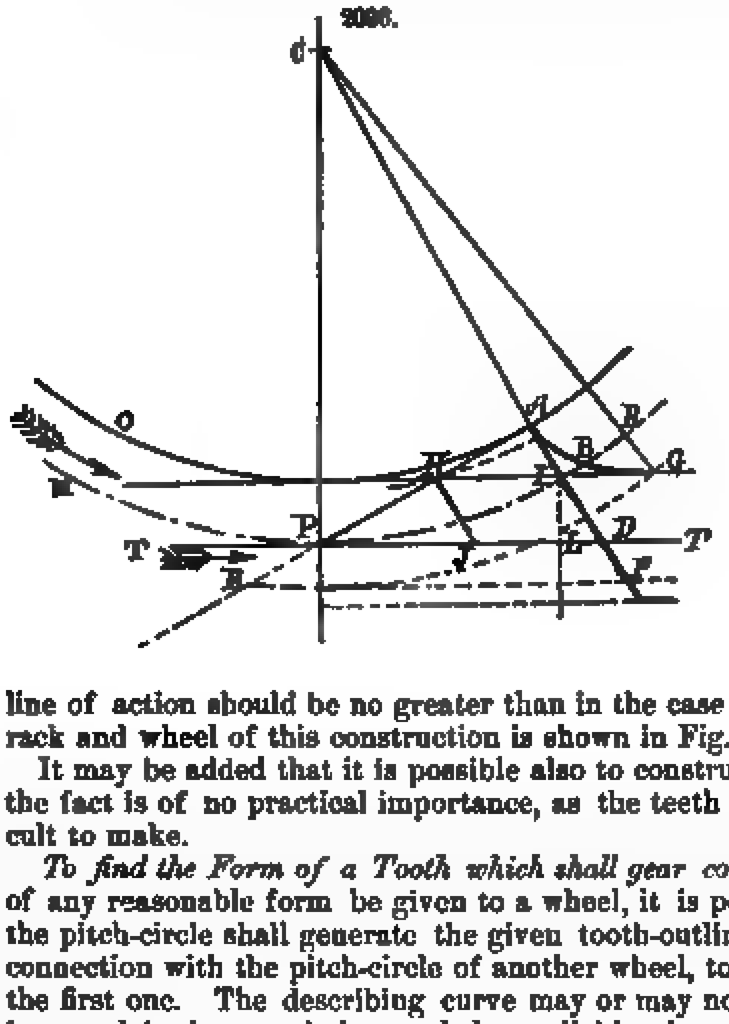
Since the involute does not continue within its circle, it is clear that in Fig. 2091 $A\,F$, $B\,E$ are the greatest lengths of the acting faces that can be used; and if they are used, the teeth will be pointed, as $A\,G\,U$, $B\,H\,W$. Considering D as the driver, the action begins at A; and when I and J meet at P, the marking-point having traveled from A to P, the curve $I\,A$ will have the position $P\,V$. The arc of approach $A\,V$ being thus equal to $A\,P$, the arc of recess $V\,E$ must be equal to $P\,B$, since $A\,E$, the whole arc of action, is equal to $A\,B$, as before seen. But $\frac{A\,P}{P\,B} = \frac{A\,D}{B\,C} = \frac{P\,D}{P\,C}$; that is to say, the arcs of approach and of recess, if the teeth be of the greatest possible length, are to each other as the radii of the pitch-circles, or as the radii of the base-circles, of the driver and the follower respectively. But as it is not necessary that the full length of the curves should be used, the arcs of recess and approach may be proportioned at pleasure by properly adjusting the lengths of the teeth.

The diagram, Fig. 2091, is made without any regard to practical proportions, for the sake of perspicuity, the obliquity of $A\,B$, as well as the pitch, being plainly excessive. In practice, the angle between $A\,B$ and $T\,T$ should never exceed 20° if it be possible to keep it within that limit, and it is better that it should be no more than from 15° to 17°; and the laying out of working teeth is illustrated in Fig. 2092. Through P are first drawn $C\,D$, the line of centres, an arc of each pitch-circle, and $T\,T$, the common tangent, from which is measured the angle of the line of action $A\,B$, which in this case is 17°, by which the radii of the base-circles are determined. Then also through P are drawn $P\,G\,V$, $P\,L\,W$, the involutes of the lower and upper base-circles. Supposing the number of teeth to be assigned, the pitch, and the thickness of the tooth as measured on the pitch-circle, are known. Now, if we assume the height of the tooth of D, taking for instance G as the highest point, we may find the arc of action on the right of $C\,D$ thus: Through G describe a circular arc with D as its centre, cutting $A\,B$, the locus of contact, in I; then $P\,I$ will be equal to the arc of action *on the base-circle* through A, from which that on the pitch-circle is readily found, subtending the same angle. Or if that part of the angle of action be assumed, we can by reversing this process find $P\,I$, and thence determine G. Draw $G\,D$ cutting the pitch-circle in J: then, if $P\,J$ be just half the thickness of the tooth, the latter will be pointed; if less, the tooth may be topped off as in the figure, while if greater the assumed conditions cannot be satisfied. By a proceeding exactly similar, in the case of the upper wheel, we determine the height of its tooth; and, setting off from P the thickness on each pitch-circle, the opposite sides of the teeth are bounded by similar and reversed involutes. The clearing spaces of the upper wheel may be of any forms which will not touch the epitrochoids marked on the plane of that wheel by the points in the outer edge of the tooth of the lower one, and in a similar manner the forms of those in the lower wheel may be determined.

Rack and Wheel with Involute Teeth.—We have already met with one case in which the tooth of a wheel working with a rack, or at least that part of it lying without its pitch-circle, is of the involute form. This was shown in Fig. 2080; but, as there pointed out, it was the involute of the pitch-circle, and the action was objectionable as confining the wear to a single point of the rack-tooth. A

better method of constructing involute rack-work is shown in Fig. 2093. Let C be the centre of the pitch-circle $M\,P\,B$, and $T\,T'$ the pitch-line of the rack. Draw through P, the point of contact, a line of action $E\,A$ making any angle with $T\,T'$; let fall $C\,A$ perpendicular to $E\,A$, producing it to cut $T\,T$ in D; then $\frac{C\,A}{C\,P} = \frac{P\,A}{P\,D}$. Therefore a pencil at P, traveling from P to A in a right line while the rack moves through the distance $P\,D$, the wheel turning also as shown by the arrows, will trace on the plane of the rack the right line $D\,A$, and on that of the wheel the involute $B\,A$ of the base-circle $A\,O$. By reversing the rotation and letting the pencil travel from P to E, we should evidently obtain the extension $B\,G$ of the curve and $D\,F$ of the right line, and it is equally clear that by thus reversing the direction, the curve $A\,B\,G$ will drive the rack to the left with a constant velocity ratio, the locus of contact being $A\,E$. The point A limits the top of the rack-tooth and the bottom of the acting wheel-tooth, the action in the case above supposed beginning at A and ending at E; the latter point being found, if G be assumed, by describing a circle through G to cut the line of action: by drawing through E a parallel to $T\,T$, we find F, the point of the rack-tooth which will meet G in the action. So if we assume I as the highest point of the rack-tooth, a parallel to $T\,T'$ through I cuts $E\,A$ in H, giving $H\,P$, which will be equal to the arc of action on the right of $C\,P$, measured on the base-circle: on the pitch-circle or on the pitch-line of the rack, it will be $J\,P$, found by drawing $H\,J$ perpendicular to $E\,A$, cutting $T\,T$ in J. If I be assumed, $D\,L$, found by dropping from I a perpendicular on $T\,T$, must not be greater than half the thickness of a tooth, and should be less; and the same is true of $B\,R$, the intercept on the pitch-circle between B and the radius $C\,G$. As in Fig. 2091, practical proportions are in this diagram disregarded; the obliquity of the

2093.



2094.

line of action should be no greater than in the case of two wheels, and the appearance of a working rack and wheel of this construction is shown in Fig. 2094.

It may be added that it is possible also to construct annular gearing with involute tooth-lines; but the fact is of no practical importance, as the teeth of the outer wheel will assume a form very difficult to make.

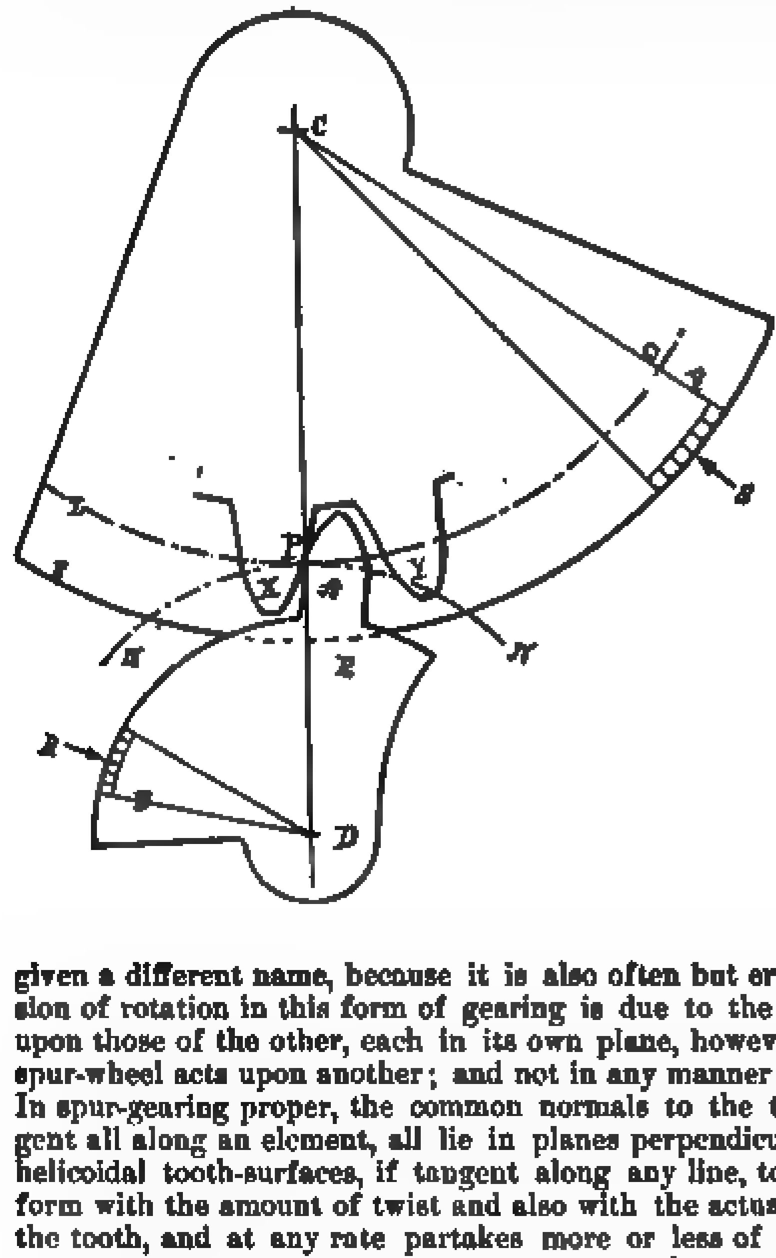
To find the Form of a Tooth which shall gear correctly with one whose Form is given.—If a tooth of any reasonable form be given to a wheel, it is possible to find the curves which by rolling upon the pitch-circle shall generate the given tooth-outline; and, by using the same describing curves in connection with the pitch-circle of another wheel, to construct a tooth which will work correctly with the first one. The describing curve may or may not be a circle; but the operation above described is more laborious, and the result less reliable, than the mechanical method illustrated in Fig. 2095. Let the form of the assigned tooth, A, be accurately cut out as part of a piece of cardboard of the form of a sector $E\,E$, whose centre is D, that of the given pitch-circle, $M\,A\,N$; which is to be drawn on the tooth, cutting its outline at P. Cut out also another sector, $F\,F$, on which describe the pitch-circle $L\,O$ of the other wheel, and also a radial line $C\,P$. Draw on the first sector the radius $D\,P$; then by making P on the one coincide with P on the other, and setting the two radii by the same straight-edge, the proper distance between the centres will be fixed, and each sector may then be fastened to the drawing-board by a pin through its own centre, being thus free to turn. $E\,E$ being uppermost, as shown, the outline of the tooth is to be traced on the lower sector. Then turning it through a small angle, $F\,F$ is to be turned also through a corresponding angle, which will depend upon the ratio of the diameters of the pitch-circles, and the outline of A traced again. By marking on each sector the angle subtended by a given length measured on its pitch-circle, and graduating its edge by subdividing this angle into the same number of equal parts on each sector, the corresponding movements of the two may be readily and accurately adjusted by reference to two fixed marks on the drawing-board, as shown at R, S. Now, in every position of A relatively to the tooth with which it is to gear, it must be tangent to it somewhere. By tracing the outline of A repeatedly, we simply keep a record of the different positions, and by drawing a line tangent to them all, as thus traced, we must have the form of the tooth to which it was thus tangent. If this operation be carefully performed, and a sufficient number of positions of A traced, we shall find the space

on the lower sector, between the adjacent teeth X, Y, covered with fine lines, and the forms of those teeth accurately mapped out.

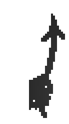
Non-symmetrical Teeth.—Were the two sides of the tooth A in Fig. 2095 exactly alike, it would be unnecessary to map out in the manner described more than the outline of the single tooth X. Now it is usual to make a wheel-tooth symmetrical about its central radius, the opposite sides being formed of similar curves, as we have all along supposed to be done. But this is of course not essential; the fronts and backs of the teeth, being entirely independent of each other, may be formed by using different describing curves: thus, as in Fig. 2096, we may make teeth of the involute form on one side and epicycloidal on the other, if for any reason it should be thought desirable.

Twisted Spur-Gearing.—If we suppose a pair of ordinary spur-wheels to be split tranversely into thin laminæ, each of these thin spur-wheels will correctly drive the one with which it is in gear. If in Fig. 2097 we suppose the laminæ of which the lower wheel D is composed to be twisted upon each other to the right, so that each one shall overlap the one below it to the same extent, those of the other wheel, C, will be driven round to the left. The original tooth-surfaces of the wheels were composed of rectilinear elements parallel to the axes; if we suppose these laminæ to be of no sensible thickness, infinite in number, and uniformly twisted or rotated past each other, these rectilinear elements will become helices. If the laminæ be of sensible thickness, we shall have what are called stepped wheels, those which are fixed upon the same axis, and constitute practically one wheel, being yet essentially distinct wheels in different phases of action; nor is this fact altered by any diminution in the thickness of the laminæ. When that diminution reaches the limit, and the tooth-surfaces are composed of helical elements, we have what is known as Hooke's spiral gearing, to which we have

2095.



2097.



given a different name, because it is also often but erroneously called *screw*-gearing. The transmission of rotation in this form of gearing is due to the successive action of the laminæ of one wheel upon those of the other, each in its own plane, however thin they may be supposed, exactly as one spur-wheel acts upon another; and not in any manner or degree to the helical form of the elements. In spur-gearing proper, the common normals to the tooth-surfaces, which being cylindrical are tangent all along an element, all lie in planes perpendicular to the axes. In twisted spur-wheels, the helicoidal tooth-surfaces, if tangent along any line, touch each other along one which will vary in form with the amount of twist and also with the actual form of the transverse section or outline of the tooth, and at any rate partakes more or less of the helical form. The common normals will therefore not lie in planes perpendicular to the axes; the consequence of which, and of whatever may be screw-like in the action of the wheels, is to produce, not rotation, but end-pressure in the lines of the axes.

The advantage of thus twisting the teeth arises from the fact that different phases of the action exist in every position of the wheels relatively to each other. The action of a pair of spur-wheels is at its best when the point of contact is on the line of centres, or more properly, since they have sensible thickness, when the element of contact is in the plane of the axes. And if a pair of spur-wheels of any given thickness be twisted through angles measured by the arcs of action, it is clear that there will always be one point of contact in the plane of the axes. This being the case, it follows that if desired the transverse sections, or tooth-outlines, may be such that the action of one upon the other shall *begin and end* upon the line of centres, continuing but for one instant. This is easily done, as may be seen in Fig. 2098, where both wheels are shown with radial flanks to the teeth.

Were the wheels to work in the ordinary way as spur-wheels, the faces of the teeth of D should be formed by rolling the upper describing circle upon the lower pitch-circle; but now they may be of any form that will lie *within* the epicycloids that would be thus generated, but should be tangent to the radial flanks of D; and a similar argument holds in relation to the upper wheel. When this is done, the sliding disappears, and the wheels work in pure rolling contact; but there is at any instant only a single point of tangency, which must bear all the pressure, and this travels along the wheels from end to end as they turn. The action is, however, remarkably smooth and noiseless, so that such wheels are peculiarly fitted for high velocities under moderate pressures.

But, whatever the form of the section, the tooth will ultimately become a helical element of the pitch-cylinder. In Fig. 2099, $A\,B$, $C\,D$ are the axes of the cylinders $E\,H$, $E\,I$, tangent along the element $E\,L$. Let the twist be such that on the lower cylinder the elementary tooth shall be the helix $E\,F$; then that upon the upper will be the helix $E\,G$, the axial advance being the same, but the perimetral travel being at rates which are to each other inversely as the diameters of the cylinders, since the arcs whose projections are $L\,F$, $L\,G$ must be equal in length by the mode of derivation. These helices must coincide when developed upon the common tangent plane; hence, if one be assumed, the other may be found by developing the first and then wrapping it upon the other

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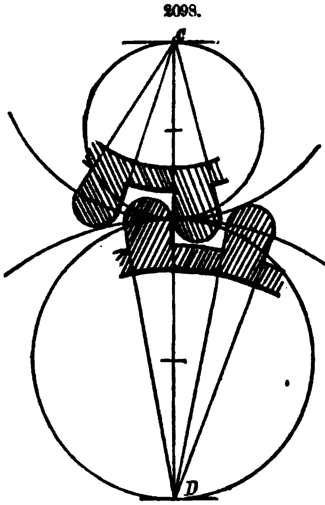

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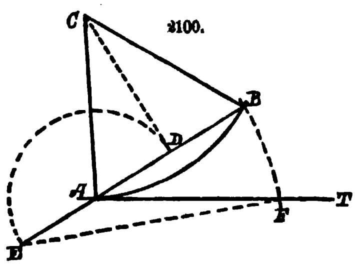

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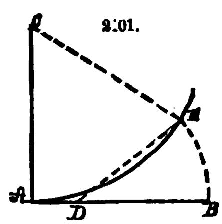

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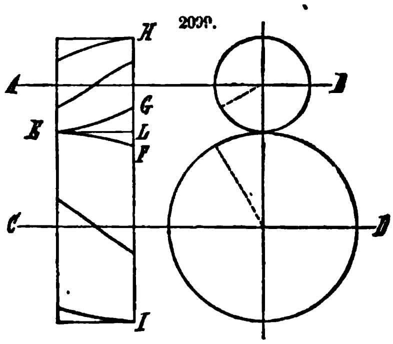

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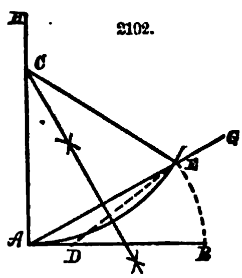

cylinder. The cylinders in Fig. 2099 are externally tangent, and it is obvious that if the helix on one be right-handed, that on the other will be left-handed. An annular wheel, with its pinion, may be also made with twisted teeth in the same manner. In this case, the larger pitch-cylinder being internally tangent to the smaller, the helices will be either right-handed or left-handed on both. And it will readily be seen that a wheel gearing with a rack may be modified in the same way: each lamina of the rack being advanced beyond the succeeding one to the same extent, in twisting the wheel uniformly, it is clear that the tooth-surfaces of the former will be composed of right lines, oblique to the plane of rotation. And when the teeth of the wheel ultimately become helical elements of the pitch-cylinder, those of the rack will become right lines in the tangent-plane, coinciding with the developments of those helices. The pressure in the direction of the axes, above mentioned, may be neutralized by making each wheel in two parts, one of which is twisted in one direction, and the other in the opposite.

On the Drawing of Epitrochoidal Curves.—All curves traced by a marking-point carried by one line which rolls upon another are called epitrochoids; and among them are the cycloid, epicycloid, hypocycloid, and involute, forming the outlines of the teeth of wheels. The following graphic pro-

cesses will be found of great utility and convenience in many operations besides that of drawing the curves above mentioned.

I. *To find approximately the length of a given circular arc.*—Let C, Fig. 2100, be the centre of the circular arc $A\,B$. At A draw the tangent $A\,T$; draw the chord $B\,A$, bisect it at D, and produce it to E, making $A\,E = A\,D$. With centre E and radius $E\,B$ describe an arc cutting the tangent in F. Then $A\,F$ will be approximately equal in length to the given arc $A\,B$. It is stated by Prof. Rankine, from whom these processes are taken, that if the angle $A\,C\,B$, subtended by the given arc, be 60°, $A\,F$ thus determined will be too short by about $\frac{1}{900}$ of its own length. Also, the error varies as the fourth power of the angle; so that if an arc of 30° be rectified by this process, the theoretical error will be reduced to $\frac{1}{14400}$.

II. *On a given circle to lay off an arc approximately equal in length to a given straight line.*—Let the given line $A\,B$, Fig. 2101, be tangent at A to the given circle. On $A\,B$ make $A\,D = \frac{1}{4}\,A\,B$; with D as centre and $D\,B = \frac{3}{4}\,A\,B$ as radius, describe an arc cutting the given circle in E; then will $A\,E = A\,B$, nearly. The error in this construction is the same as in the preceding one, and follows the same law. If then $A\,E$, when found as above, subtends an angle of more than about 60°, the given line $A\,B$ may be subdivided, and the arc corresponding to any fraction of it determined.

III. *To find the radius of a circle on which an arc of a given length shall measure a given angle.*—Let $A\,B$, Fig. 2102, be the length of the arc. Draw the indefinite line $A\,G$, making the angle $B\,A\,G$ half the given angle; also draw $A\,H$ perpendicular to $A\,B$. Set off as before $A\,D = \frac{1}{4}\,A\,B$, and with centre D and radius $D\,B$ describe an arc cutting $A\,G$ in E. Bisect $A\,E$ by a perpendicular cutting $A\,H$ in C; then $A\,C$ is the radius sought. For, drawing the arc $A\,E$ and the radius $C\,E$, the angle $B\,A\,E$, between the chord and the tangent, is half the angle $A\,C\,E$ at the centre.

This being only an application of the preceding process, and involving the same error, if the given angle be over 60°, both it and the given line should be subdivided. By this method we may readily find the diameter of a circle when the circumference is given; for, making $A\,B$ one-sixth of the given circumference, and the angle $B\,A\,G$ equal to 30°, we at once have $A\,E$ the radius.

The Cycloid.—Let the circle whose centre is C, Fig. 2103, roll on the right line $A\,B$, to which it is tangent at P; then a marking-point at O in the circumference will trace the cycloid $O\,R\,D$. Divide the semi-circumference $P\,O$ into equal parts at 1, 2, 3, etc.; set off $P\,D$ equal to this semi-circumference, and divide it into the same number of equal parts at the points correspondingly numbered. The number of subdivisions is immaterial; practically the six shown are sufficient and the most readily made, $P\,D$ being found by rectifying $P\,2$ as above explained, and setting off the length thus determined three times from P. The points 1, 2, 3, etc., on the circle, will come successively into contact with the points 1′, 2′, 3′, etc., on the tangent; and the centre, traveling in the line parallel to $A\,B$, will be always vertically over the point of contact. Thus, when $C\,2$ becomes the contact-radius, it will have the position $E\,2'$; when $C\,4$ is the contact-radius, the centre will be at F, and so on. But the distance from O to the point 2 on the circle is the same when the centre is at E as when it is at C: if then we set off from the point 2′ on the tangent the chord $2'\,R = O\,2$ on the circle, $E\,R$ will be the position of the *generating radius* $C\,O$ for that position of the circle, and R a point on the cycloid. When C has reached F, $C\,4$ being contact-radius, the generating radius will be $F\,S$, the chord $4'\,S$ being made equal to the chord $O\,4$; and in like manner any number of points may be found. When O reaches D, the radius $C\,O$ will have the inverted position $G\,D$, to which the cycloid is tangent at D.

2103.

The rolling motion of the circle is compounded of a rotation on its axis and a bodily translation in the direction $C\,G$. We may imagine these motions to take place separately and successively, instead of simultaneously, and thus find points in the cycloid in another way. If, for instance, we suppose the circle to be turned round its centre C until $C\,2$ takes the place of $C\,P$, this will bring the generating radius $C\,O$ to the position $C\,4$; if we then push the circle forward through a distance $C\,E$ equal to the arc $2\,P$ or $O\,4$, we shall have the generating radius $E\,R$ in its correct position, parallel to $C\,4$. So also if O be turned round C to the point 2 on the circle, and then pushed forward to S, the distance $2\,S$ being equal to the arc $O\,2$, then S will be a point on the cycloid.

But a more rapid and accurate method of drawing the curve is by means of tangent arcs. This method depends on the fact already stated, that in rolling contact the point of tangency is in the instantaneous axis. Thus, in the original position of the circle, P is the instantaneous centre; and when the circle begins to roll, every point in or connected with it is at the instant in the act of describing a circle of which P is the centre. If then we describe an arc about P with radius $O\,P$, the direction of that arc is also the direction of O's path at that instant. When $C\,2$ becomes the contact-radius, the instantaneous centre will be the point 2′ on $A\,B$. But as the chord $O\,2$ of the circle does not change its length, it must then be the instantaneous radius; therefore, if about 2′ on the tangent, with radius $2'\,R = O\,2$, we describe an arc, it also will coincide in direction with the path of O at the instant. Now the direction of a curve at any point is that of its tangent at that

point; and these arcs being traced by O, which also traces the cycloid, it follows that the latter curve is tangent to the arcs. If then we take as centres the points 1′, 2′, 3′, etc., on $A\ B$, and about them describe arcs, using as radii the chords O 1, O 2, etc., the envelope of these arcs, or curve tangent to them all, will be the cycloid. And these arcs serve better as guides in drawing the curve than actual points would, since they do give an indication of its direction, while the points do not. By making a greater number of subdivisions and striking a greater number of arcs, the cycloid may be mapped out with any desired degree of precision, though not a single point be found. Should the point of the curve corresponding to any point of contact, as for instance 2′ on $A\ B$, be required, it is quickly found by erecting the perpendicular 2′ E to locate the centre, and cutting the cycloid by an arc of the describing circle, which will of course give R the extremity of the instantaneous radius for the point selected. This instantaneous radius is of course the normal, and $T\ R\ T$ perpendicular to it is the tangent, to the cycloid at R; and the radius of curvature is $R\ L$, found by prolonging and doubling R 2′; so also $M\ S$, twice the instantaneous radius 4′ S, is the radius of curvature at S.

The Epicycloid.—This curve is traced by the rolling of a circle, not upon a *base-line*, but upon the outside of a *base-circle*. In Fig. 2104, H is the centre of the base-circle, C that of the rolling one, in the circumference of which is O, the marking-point. P being the point of contact at starting, the radii $C\ P$, $P\ H$ lie in one right line; and as the point of contact must always lie on the line of centres, when C reaches E the line $E\ H$ will cut the base-circle $A\ P\ B$ at 2′, the point of contact then, and P 2′ must be equal to the arc P 2 which has rolled over it, and the path of C will be a circle whose centre is H. The first step then is to subdivide the semi-circumference $P\ O$ into equal parts at the points 2, 4 (a greater number being of course used in practice; but the analogy to the preceding figure is so close that what is here shown will suffice for illustration). On the left is shown the operation of rectifying $P\ V$, an arc equal to P 2, on the common tangent $P\ T$, and of setting off on the base-circle an arc $P\ W$ equal to the length thus found and therefore to P 2. Equal arcs P 2′, 2′ 4′, 4′ D, being then set off from P toward B, we have $P\ D$ equal to the half circumference $P\ O$. Now, when C 2 is contact-radius, E must be the centre of the describing circle; and making 2′ $R = 2\ O$, we have R, a point in the curve. Otherwise, the rolling being now compounded of a rotation about C and a *revolution* about H, we may first turn the circle in its original position until 2 reaches P, which will bring O to 4; then a circular arc through 4 with centre H will cut the describing circle in its second position at R.

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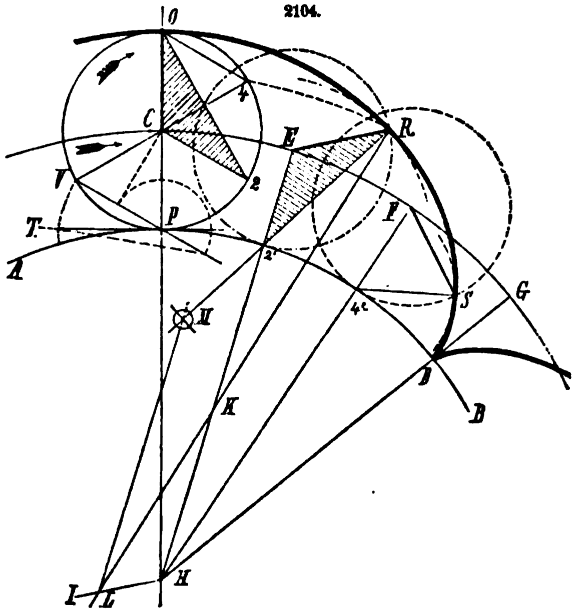
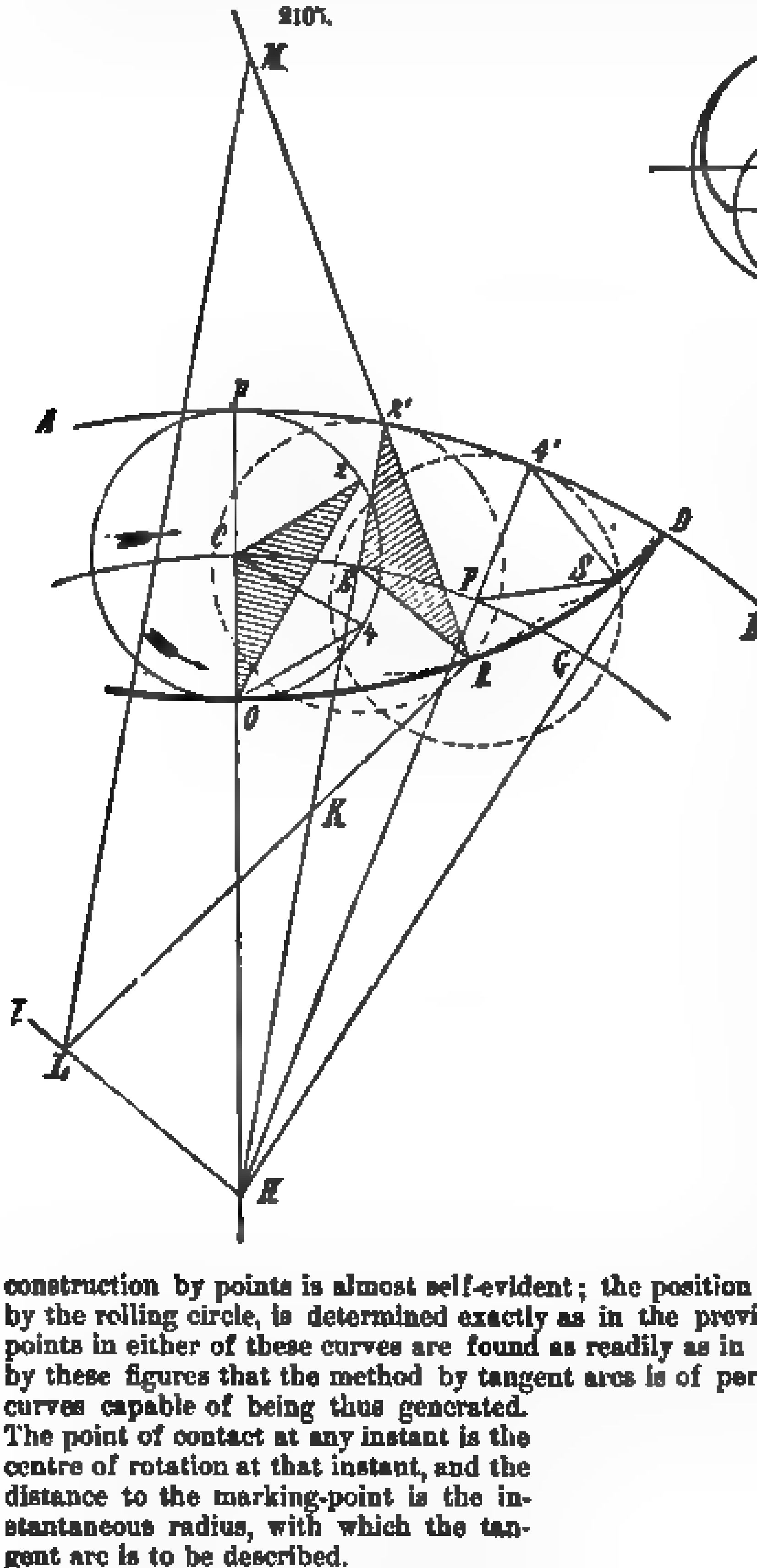


But, again, the method of tangent arcs may be used. When C 2 becomes contact-radius at E 2′, the point of contact 2′ is the instantaneous centre, 2′ R equal to 2 O is the instantaneous radius, and the curve will be tangent to the circular arc thus determined; and by repeating this as in the case of the cycloid, the curve may be most expeditiously mapped out, without finding a point in it. If the radius of curvature at any point, R for instance, be required, an arc described about R with the radius of the rolling circle will give by its intersection with $C\ G$ the path of the centre, the position of the latter when the marking-point is at R. Then $E\ H$ determines 2′, the corresponding point of contact, and the position R 2′ of the instantaneous radius, normal to the curve. Prolong R 2′ indefinitely, draw $R\ E$ the generating radius, and $H\ I$ parallel to it. Bisect 2′ H in K, draw $R\ K$ and produce it to cut $H\ I$ in L, and draw $L\ M$ parallel to $H\ E$, which will cut the prolongation of R 2′ in M, the centre of curvature.

The Hypocycloid.—This is generated by a marking-point in the circumference of a circle which rolls on the *inside* of another of greater diameter. The construction is illustrated in Fig. 2105, which is lettered throughout to correspond with Fig. 2104; and the steps of the process being identical, including the finding of the radius of curvature, no further explanation is necessary.

The Internal Epicycloid.—If one circle be internally tangent to another, and the greater roll upon the less, a marking-point in its circumference will trace what is called the *internal epicycloid*, merely to call attention to the particular mode of generation. For it is to be noted that every epicycloid may be generated by the rolling upon the same base-circle of either of two circles; and the same is true of the hypocycloid. Thus, in Fig. 2106, in the diagram on the left, let D be the centre of the base-circle, and C that of one which by rolling upon it will generate the epicycloid shown, the tangency being external. Then the same curve will also be traced by the rolling upon D of the circle E, to which it is internally tangent; the diameter of this larger circle being equal to the sum of the

diameters of the other two. Thus every internal epicycloid is also an external one; but the epitrochoids traced by points carried by these different describing circles, not on their circumferences, will not be the same. In the diagram on the right, D is the centre of the large base-circle, within which are shown two describing circles, the sum of their diameters equaling the diameter of D; and the



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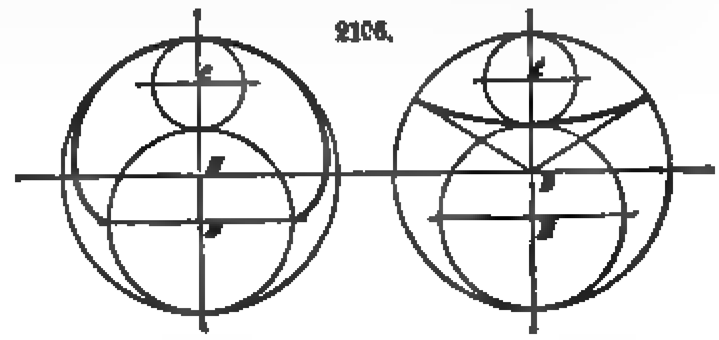


2108.

same hypocycloid will be traced by the rolling of either of them within the outer circle. In both these cases, if the curve be traced in a given direction, the two circles by which it may be generated will roll in opposite directions.

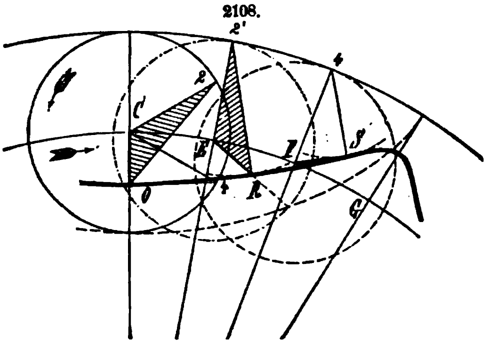
The Epitrochoid.—It is evident that the marking-point carried by a rolling circle, or other line, need not be *in* the rolling line. Although, as above stated, the term epitrochoidal is applied in general to all lines generated by marking-points so controlled, yet the name *epitrochoid* is also specifically applied in the case in which the point is carried by one circle rolling upon another, and is not situated in the circumference. If it be outside the rolling circle, the curve is called a *curtate* epitrochoid, and is looped, as shown in Fig. 2107. If the marking-point be within the rolling circle, as in Fig. 2108, the curve is waved, the marking-point never reaching the base-circle, and is called *prolate*. The epicycloid is therefore, it will be seen, but a special case, being the boundary between these two forms; and the marking-point just reaching the base-circle, there is neither wave nor loop, but the curve is tangent to the radius $G\ D$, the adjacent branches forming a cusp. The construction by points is almost self-evident; the position of the generating radius, being controlled by the rolling circle, is determined exactly as in the previous cases, and, its length being constant, points in either of these curves are found as readily as in the others. And it will be at once seen by these figures that the method by tangent arcs is of perfectly general application, in drawing all curves capable of being thus generated. The point of contact at any instant is the centre of rotation at that instant, and the distance to the marking-point is the instantaneous radius, with which the tangent arc is to be described.

The Involute of the Circle.—This may be considered in a sense the converse of the cycloid, being generated by a point in a right line rolling upon a circle. Or, what amounts to the same thing, if a pencil be fixed at the end of an inextensible string of no sensible thickness, and the string be wound upon or unwound from a circle, being held taut, it will trace the curve in question. It is easily constructed, as in Fig. 2109. The circumference being divided into equal parts at the points 0, 1, 2, etc., a tangent is drawn at each point, and on it is set off the length of the arc measured from the point of starting to the point of tangency. Thus, let the semi-circumference be unwound to the right, beginning at O; then the tangent 1 1 is made equal to the arc O 1, the tangent 2 2 to the arc O 2, and so on. The method of tangent arcs may also be used here. The points 1, 2, 3, etc., on

the circle being the instantaneous centres, the tangents 1 1, 2 2, etc., are the instantaneous radii. These tangents are also not only the normals to the curve, but also the radii of curvature at the corresponding points.

Of Circular and Diametral Pitch.—The term *pitch*, as has been explained, is used to denote the distance, measured on the pitch-circle, which is occupied by a tooth and a space; or in other words, the arc found by dividing the circumference into as many equal parts as there are teeth in the wheel.

2108.



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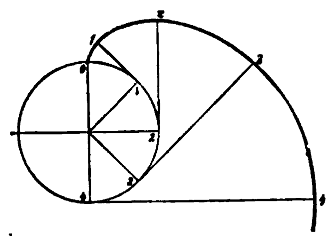


We have, then: Pitch × number = circumference; whence, if either two factors be given, we readily find the third. It is clearly more convenient to express the pitch in whole numbers or manageable fractions, as 2-inch pitch, 1½-inch pitch, and so on. But the circumference being 3.1416 times the diameter, it happens that if this system be adopted, the diameter of the pitch-circle will often involve an awkward decimal. The pitch as above defined is styled the *circular* pitch, in order to distinguish it from what is called the *diametral* pitch, the use of which is designed to avoid the inconvenient fractions above mentioned, and otherwise to facilitate the necessary calculations. The diametral pitch is simply the quotient found by dividing the diameter of the pitch-circle, instead of the circumference, by the number of teeth. Its relation to the circular pitch is clearly seen thus:

$$\text{Circular pitch} = \frac{\text{diameter} \times 3.1416}{\text{number of teeth}};$$

$$\text{Diametral pitch} = \frac{\text{Circular pitch}}{3.1416} = \frac{\text{diameter}}{\text{number of teeth}}.$$

In the practical use of this system, values of the diametral pitch are selected, being fractions having unity for the numerator and a whole number for a denominator in each case, as $\frac{1}{3}$, $\frac{1}{6}$, $\frac{1}{10}$, $\frac{1}{24}$, etc.

The denominators of these fractions are evidently the corresponding values of $\frac{\text{number of teeth}}{\text{diameter}}$, and are used to designate the wheels; thus, a "4-pitch wheel" is one of which the diametral pitch is $\frac{1}{4}$, and so on. Suppose, for example, that we wish to know the diameter of a wheel of 40 teeth, of "5-pitch": we have $\frac{40}{5} = 8$ = diameter of pitch-circle. Or if the number of teeth of "8-pitch" in a wheel of 17½ diameter is desired, we have 8 × 17½ = 140 = number of teeth.

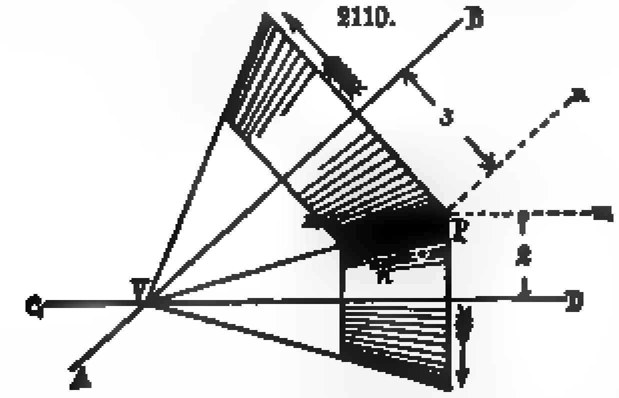
The advantage of this system lies in the obvious fact that it is practically more important to have the diameter of the pitch-circle either a whole number or a convenient fraction, than that the circular pitch should be either.

Bevel-Gearing.

Bevel-wheels are used for the transmission of motion from one axis to another which intersects it. They are also called conical wheels, because the pitch-surfaces are cones, whose common apex is the intersection of the axes. It is usually the case in practice that the positions of the axes are given, and it is required to make the wheels so as to preserve a given velocity ratio. The first step is to find the forms of the pitch-cones. In Fig. 2110, let $A\,B$, $C\,D$ be the axes, meeting at V; and let us suppose that two revolutions of the former are to produce three revolutions of the latter. Draw a line $n\,n$, parallel to $A\,B$, and at a distance from it measuring 3 on any convenient scale of equal parts; also a line $m\,m$, parallel to $C\,D$, and at a distance from it equal to 2 on the same scale. These lines intersect at P; and drawing $V\,P$, we see that it will by revolving around $A\,B$ generate one cone, while if it revolve around $C\,D$ it will generate another, the two being tangent along $V\,P$; and these are the pitch-cones required. The line $m\,m$ is here drawn within the angle $B\,V\,D$: had it been drawn within the angle $A\,V\,D$, as in Fig. 2111, we should have had a different pair of cones; the velocity ratio is the same in either case, but it will be seen that, supposing $A\,B$ to rotate in the same direction in both instances, the rotations of $C\,D$ are in opposite directions. Now, only limited portions (frusta) of these cones need or can be employed, as shown in the figures. Their distance from the vertex is immaterial, so far as the theory is concerned; and this, which also determines the actual size of the wheels, is usually decided by considerations connected with the framing of the machine or the power to be transmitted, with neither of which we have to do in ascertaining the forms of the teeth. If one shaft can be carried past the other, however, we see that we have the choice

between two pairs of wheels, each giving the same velocity ratio, but differing in regard to the directions of the rotations. The choice here is also usually determined by the conditions of the machine in which the wheels are to be used; we will therefore suppose that the pair shown in Fig. 2110 has been selected, and that the teeth are to be laid out.

The manner in which this is usually done is as follows: In Fig. 2112, $V P E$, $V P H$ are the pitch-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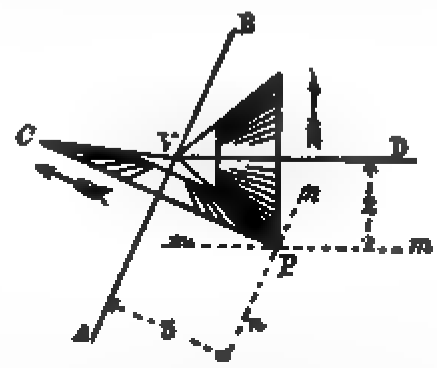
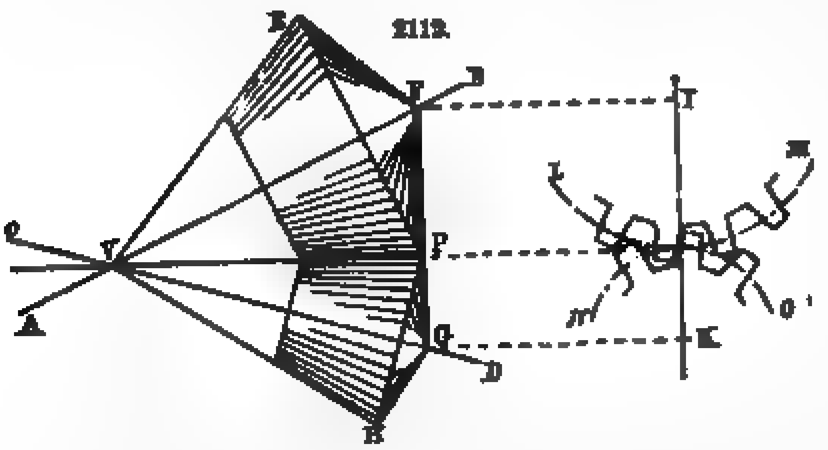
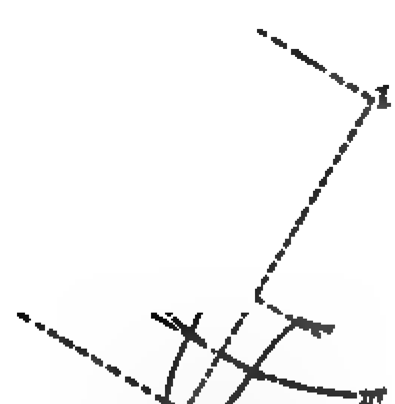

2111

cones, $V P$ being the common element, which and the axes are in the plane of the paper. Draw through P a perpendicular to $V P$, cutting $A B$ at F and $C D$ at G. Then, if $P F$ revolve around $A B$, it will generate a cone $P F E$, whose elements are normal to those of $V P E$. So also $P G$ by revolving around $C D$ generates a cone $P G H$, normal to $V P H$. These normal cones are now to be developed. It is clear that if $F G$ be the trace of a plane perpendicular to the paper, it will be tangent to both; and the right-hand part of the diagram shows the development of the cones upon it. The vertices appear as the points I, K; the base of the upper cone will be a part of the circle $L M$, whose radius is $F P$, and that of the lower will be a part of the circle $N O$, whose radius is $G P$. Upon these circles teeth are to be laid out as if they were the pitch-circles of spur-wheels, being usually made of the epicycloidal form. Were the whole surface of a normal cone developed, all the teeth laid out, a thin sheet of metal cut to the form thus found, and then wrapped back upon the cone, we should then have the outlines of the teeth on the larger end of the wheel. But in order to make the drawings, we need only lay out a single tooth on the development of each cone. Now the pitch is the same on both wheels, and when we have decided on the number of teeth, we know what it will be. We have then only to rectify such a fraction of the base-circle of either cone, $E P$


2112.

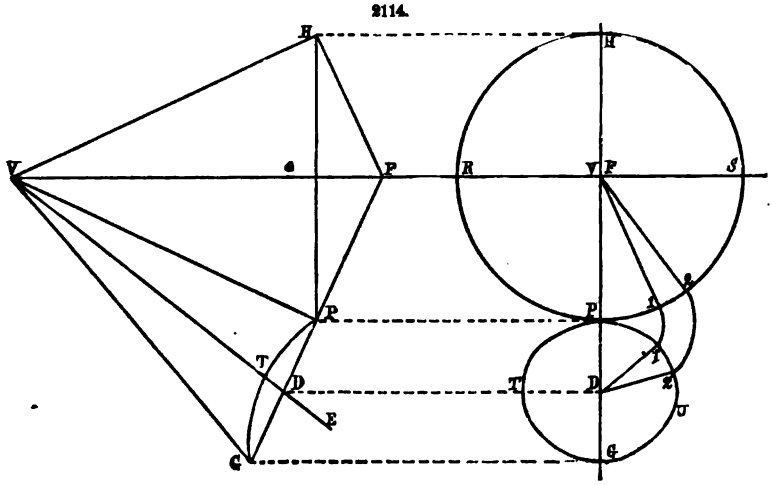


for instance, as will contain the pitch any convenient number of times, set off on each circle in the development from the point of contact an arc equal in length to this rectification, by the processes already described, and divide each of these arcs into the same number of equal parts, to obtain the correct pitch on the developed bases and construct the teeth Supposing this to be done, the mode of completing the drawing of the larger wheel is shown in Fig. 2113.

It is evident that, as the teeth project beyond the pitch-cone, both it and the normal cone must be enlarged beyond the original dimensions. Thus FP must be extended till FD is equal to the extreme radius of the developed tooth, which is projected back upon it, and the *blank* for the wheel will consist of a frustum of the cone $D\,V\,H$, joined to a frustum of the normal cone $D\,F\,H$. The bottom of the space in the development is also projected back upon $F\,P$ at E, and the top and bottom of the tooth will be bounded in the section shown in the lower half of the side view by the lines $D\,G$, $E\,K$, converging in V. Having decided on the length $P\,R$ of the tooth, the inner end is limited by another cone normal to the pitch-cone, generated by a line through R perpendicular to $V\,P$.

If a side elevation is to be drawn, the end view must be first constructed. The points D, P, E, in revolving around the axis, describe circles which correspond to certain circles in the development. Thus P describes the base of the pitch-cone, which develops into $L\,M$. In the end view, whose centre is C, this circle is seen in its true size; and the breadth of a tooth or of a space measured on this circle must be the same as the breadth measured on $L\,M$. Similarly the breadth on the outer or inner circles, described by D and E, must be the same as on the corresponding circles in the development. Since the *arcs* are equal, but the radii different, the chords will not be equal: practically, however, the difference will not be appreciable unless the wheel be of great size or the pitch very coarse; and by the processes of rectification and its converse, previously explained, the difference may be determined graphically if desired. Intermediate circles may be drawn in the development and in the projections, and similarly used, for determining the breadth of the tooth at other points, and thus fixing the outline with precision. The form at the inner end is precisely similar but smaller, and is constructed by drawing radial lines to cut the series of smaller circles described by the points G, R, K. The radius of any intermediate circle in the development being projected on $F\,D$, and a line drawn from the point thus found toward V, cutting $G\,K$, we shall have the point which will

2114.



describe the corresponding intermediate circle at the inner end of the tooth. The drawing of one tooth in the end view being completed, the others are copied in their proper positions, and the various points projected to the corresponding circles in the side elevation, where, being seen edgewise, they appear simply as right lines, $G\,J$, $D\,H$, etc. Since all the elements of the tooth-surfaces converge in V, it is better here also to determine only the forms of the teeth at the outer end by projection from the end view, and to draw converging lines toward V to find such outlines as may be visible at the inner end.

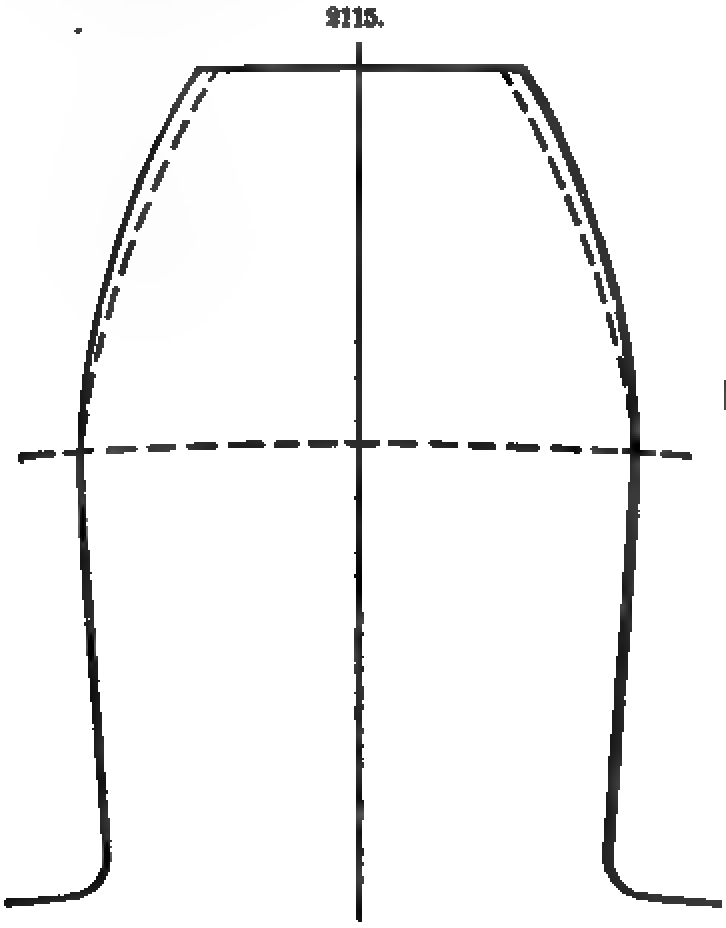
This method of laying out the teeth is, however, only approximately correct. In spur-gearing the tooth-surface is generated by the element of a describing cylinder rolling in contact with the pitch-cylinder; and it can be shown that in an analogous manner the tooth-surface should be generated by the element of a describing cone rolling with the pitch-cone. By following the motion of the describing element of this auxiliary cone, and finding the points in which in different positions it pierces the normal cone, we can construct the trace upon the latter of the surface thus generated, or in other words the outline of the correct tooth. The error of the method first described, then, consists in the assumption that this outline when developed will be a true epicycloid, hypocycloid, or involute, as the case may be.

In Fig. 2114, $P\,V\,H$ is a pitch-cone, $P\,F\,H$ its normal cone, and $P\,V\,G$ a describing cone, which by rolling on the outside of $P\,V\,H$ will generate the surface of the face of the tooth. The normal cone is to be extended as far as may be necessary to determine the line in which the describing cone intersects it; in the side view this line is $P\,T\,G$, and in the end view, which is a projection on a plane perpendicular to $V\,F$ (the axis of the pitch and normal cones), it appears as the curve $P\,T\,G\,U$. Now, taking $P\,V$, the common element at starting, for the describing line, it is clear that if the cone $V\,P\,G$ were to turn while the normal cone did not, that element would trace on the latter merely this line of intersection. But the normal cone does turn, and, the ratio of the two velocities being known, we can easily find the actual trace of $V\,P$ upon it by the aid of this line of intersection.

Thus, let the lower cone turn until $D P$ appears in the end view as $D 1'$; then the upper cone will have turned through the known angle $P V 1$, and the curve $1 1'$ must meantime have been traced upon it. So when $D P$ has gone to $D 2'$, $P V$ will have gone to $V 2$, and the curve $2 2'$ will have been traced, and so on.

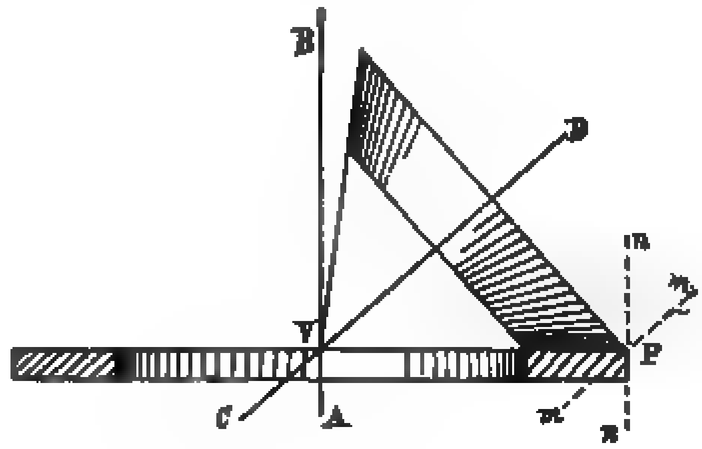
As an illustration of the extent of the error in the approximate method, we show in Fig. 2115 a full-size outline of a tooth as determined by it, and also as found by the process just explained.

2115.

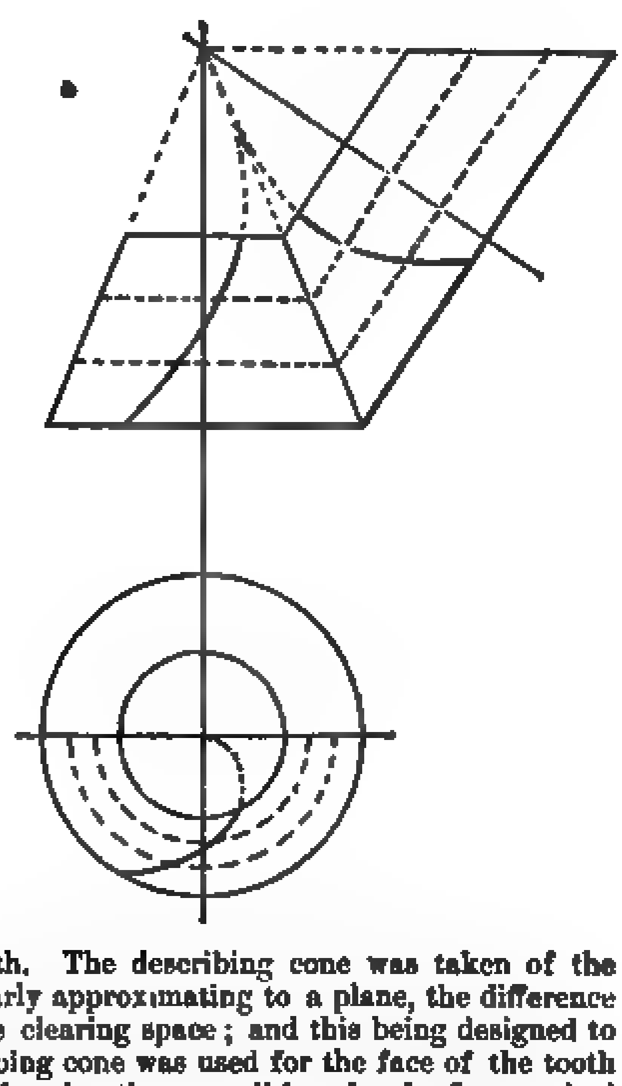


2116.

2117.



2118.



The wheel is one of 30 inches diameter, with 24 teeth. The describing cone was taken of the diameter which would generate a flank surface most nearly approximating to a plane, the difference being inappreciable within the limit of the depth of the clearing space; and this being designed to gear with another wheel exactly similar, the same describing cone was used for the face of the tooth also. The form of the tooth which would be determined under these conditions by the first method is shown in dotted lines; the full lines being of the correct form as found by the second method. The discrepancy is quite marked, and sufficient to make a material difference in the smoothness of the action and in the durability of the wheels.

It was remarked in connection with Figs. 2110 and 2111 that, with a given pair of axes and a given velocity ratio, it is always possible to construct two pairs of pitch-cones, of which the directional relations are different. Of these, one pair will always be in external contact; but, as shown in Fig. 2116, the other pair may be such that one of the two shall touch the other internally. In this case the methods of constructing the teeth will be analogous to those used in annular spur-gearing. Or again, as in Fig. 2117, the common element $V P$, as determined by the process described, may be perpendicular to one of the axes, the pitch-cone thus degenerating into a plane. The normal

cone then becoming a cylinder, its base will develop into a right line, and the construction of the teeth by the first method will be similar to that applicable in the case of a rack and wheel.

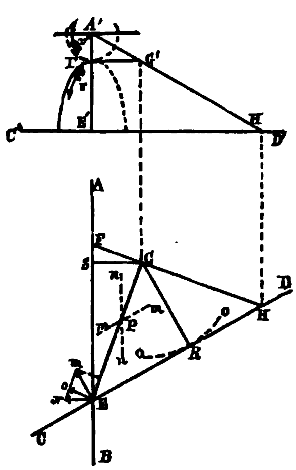
Twisted Bevel-Wheels.—We may suppose a pair of bevel-wheels to be cut transversely into thin laminæ, as we did in the case of two spur-wheels. Each of these thin wheels will drive its mate, and as before we may twist them round so that each one shall overlap the next one on the same axis, to the same angular extent. Supposing the laminæ to be of inappreciable thickness, we shall thus transform the converging rectilinear elements of the tooth-surfaces into conical helices; and if the teeth be now made indefinitely small and numerous, they will ultimately become such conical helices lying on the pitch-surfaces, as shown in Fig. 2118. We may thus attain in bevel-gearing the same advantages that were shown to belong to twisted spur-gearing. Nor would it be difficult to make the teeth of this form in any engine in which it is possible to cut bevel-gearing correctly. Spur-wheels, as is well known, may be cut with precision by a milling-cutter whose outline is that of the space between two teeth, because the elements of the teeth are parallel to the axis, and the space everywhere of the same size and form. But the space between two teeth of a bevel-wheel continually changes its size, and though the outlines of parallel sections are all similar, they are of different curvatures. Consequently the teeth can only be formed accurately by planing, as in the cutting engine of Corliss, the tool traveling always in a line toward the vertex of the pitch-cone. Now, if the blank be made to rotate uniformly during each cut, the desired twist may be given to the teeth with ease and perfect accuracy.

SKEW-GEARING.

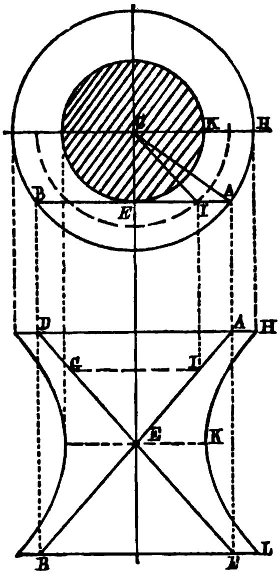
When two axes lie in different planes, motion may be and often is transmitted from one to the other by means of two pairs of bevel-wheels; a third axis being introduced, cutting the other two. But it is possible to make a pair of wheels, one upon each shaft, whose teeth shall be composed of rectilinear elements, touch each other in a right line, and transmit rotation with a constant velocity ratio directly, thus dispensing with the countershaft and one pair of bevel-wheels. It is usually the case that the positions of the axes and also the velocity ratio are fixed by the requirements of the mechanism in which the wheels are to be used.

In Fig. 2119, let $A\ B$ represent one axis, supposed to be vertical and parallel to the paper; let $C\ D$, also parallel to the paper, represent the other axis. These projections intersect at E, which point represents the common perpendicular of the axes; this line, being horizontal, will be seen in its true length $E'\ A'$ in the top view above, where A' represents the vertical and $C'\ D'$ the inclined axis. The lines $n\ n$, $m\ m$ are now drawn parallel to $A\ B$ and $C\ D$, at distances from them which are to each other in the inverse ratio of the given angular velocities; these intersect at P, and $P\ E$ will here, as in the case of bevel-wheels, represent in this view the common element of the pitch-surfaces, which will also be parallel to the paper. Through any point of this line, as G, another line $F\ H$ can be drawn perpendicular to it, and so as to cut both the axes. Its vertical projection $F\ H$ will be perpendicular to $G\ E$, because the latter is parallel to the paper; in the horizontal projection, F, being a point in the vertical axis, will appear as A', and H will appear as H' in $C'\ D'$, thus giving $A'\ H'$ as the horizontal projection of $F\ H$. Now project G to G', draw $G'\ I'$ parallel to $C'\ D'$, and it will be the horizontal projection of $G\ E$. This line lies in a plane parallel to both

2119.



2120



axes, and intersects at I', their common perpendicular, dividing it into segments proportional to $A'\ G'$, $G'\ H'$, and therefore to $F\ G$, $G\ H$: by revolving around $A\ B$ it will generate one surface, and by revolving around $C\ D$ it will generate another, tangent to the first, which will be the pitch-surfaces of the wheels.

These surfaces are readily constructed, as in Fig. 2120, where the inclined line $A B$ revolves about the vertical axis, its least distance from which is $C K$. Each point in revolving describes a horizontal circle, whose radius is seen in its true length in the top view. It will be seen that the same surface will be generated by a line seen as $D F$ in the front view, and as $B A$ in the top view; for D and A describe the same circle; so also do G and I; and the same is true of any two points in these lines which lie in the same horizontal plane.

The two surfaces generated by the line $G E$ of Fig. 2119 are shown in position in Fig. 2121; the generatrix being prolonged to L, so that the end planes are equidistant from the *gorge-circles*, as the transverse sections through E are called. These surfaces are called hyperboloids of revolution, as it can be shown that the meridian section of each (as $H K L$ of Fig. 2120) is a hyperbola. Their action consists of rolling, with however a sliding in the direction of the common element, because the two circles which move in contact have not a common tangent. To make this clear, the gorge-circles of the two pitch-surfaces are shown in Fig. 2119, in dotted lines, in the top view; their common point is I'; and if the inclined one turn, it will cause the vertical surface to rotate, the directional relation being shown by the arrows. In the other view the common point of these two circles is E; and at the instant the linear velocity of the inclined circumference may be represented by $E M$, a tangent to it, of any length; at the same instant that of the other gorge-circle must be also represented by its tangent $E N$. The length of the latter is determined by the consideration that no motion in the direction $E G$ would transmit rotation, which is effected solely by the component $E O$ of the supposed motion $E M$, which is perpendicular to $E G$, $O M$ being the tangential or sliding component; and the resultant $E N$ must have the same normal component. Now the angular velocities will be equal to the linear velocities $E M$, $E N$, divided by the radii $I' E'$, $I' A'$;

and recollecting that $\frac{I' A'}{I' E'} = \frac{A' G'}{G' H'} = \frac{F G}{G H}$, we will let

v = angular velocity about inclined axis $C D$,
v' = angular velocity about vertical axis $A B$.

Then we have

$$\left.\begin{aligned} v &= \frac{E M}{I' E'} \\ v' &= \frac{E N}{I' A'} \end{aligned}\right\} \therefore \frac{v}{v'} = \frac{E M}{E N} \times \frac{I' A'}{I' E'} = \frac{E M}{E N} \times \frac{F G}{G H}, \text{ or,}$$

from similar triangles $M E N$, $E F H$, $= \frac{E H}{E F} \times \frac{F G}{G H} = \frac{E H}{G H} \times \frac{F G}{E F}$.

But from similar triangles $E G H$, $E G R$.............. $\frac{E H}{G H} = \frac{E G}{G R}$;

and from similar triangles $E G F$, $E G S$.................... $\frac{F G}{E F} = \frac{G S}{E G}$;

whence $\frac{v}{v'} = \frac{E G}{G R} \times \frac{G S}{E G} = \frac{G S}{G R}$,

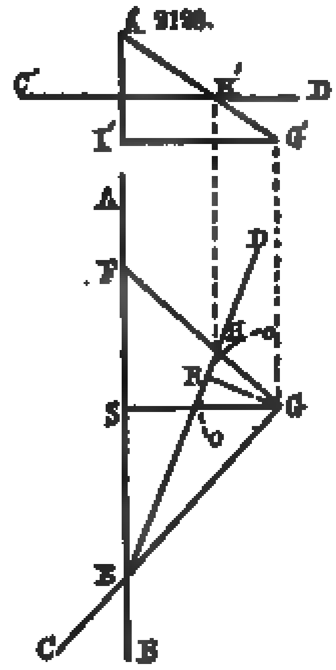
which demonstrates the correctness of the process of constructing the surfaces, as previously described.

In practice thin sections or frusta only of the surfaces are used. In Fig. 2122 are shown three pairs, either or all of which may be used, the hyperboloids being the same as in Fig. 2121. The

2121.

2122.

2120.



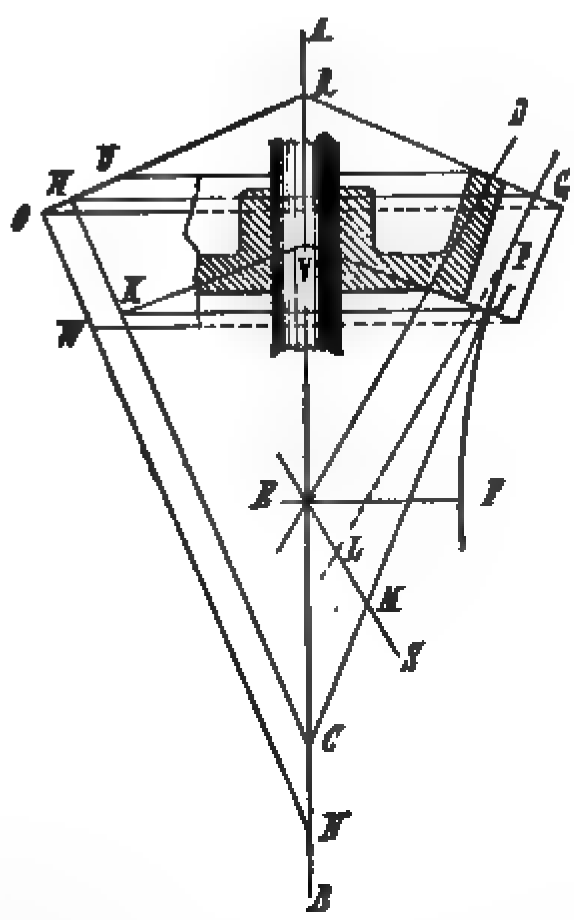
gorge-circles are the mid-planes of the central pair; but practically the wheels will work better the farther they are from the gorge-planes, as the *transverse obliquity* of the common element diminishes

as it recedes from them. For the least distance between the axes is a constant, and at an infinite distance from their common perpendicular the effect of their separation becomes imperceptible, so that the wheels will not differ appreciably from common bevel-wheels.

These wheels are now to be furnished with teeth; and the proper surfaces are generated in a manner exactly analogous to that employed in the cases of spur and bevel gearing. That is to say, a describing hyperboloid is used, which, moving in contact with both pitch-surfaces, will sweep out, as the rotation progresses, a flank for one and a face for the other. If in Fig. 2121 we suppose the inclined hyperboloid to be the pitch-surface of a wheel intended to work with another equal and similar to itself, then the vertical one may be considered as the describing surface, which by rolling upon the other in external contact, as there shown, will generate the *face-surface* for its tooth. But if we consider these, as we have hitherto done, to be the pitch-surfaces, from which it is required to construct the teeth for either of the pairs of wheels shown in Fig. 2122, then the first step is to determine the describing hyperboloid; and for convenience, this should be such as to roll with either pitch-surface with a velocity ratio expressible in whole numbers. Now, referring to Fig. 2121, the angular velocity of the inclined hyperboloid is to that of the vertical one as $G\,S$ is to $G\,R$. Supposing then that, the vertical one and the velocity ratio being given, it had been required to find the inclined one, we should have proceeded thus: Knowing $G\,S$ and the velocity ratio, we find the value of $G\,R$, with which as radius describe about G the arc $o\,o$, and through E draw $C\,D$ tangent to this arc, thus determining the vertical projection of the required axis. Through G draw $F\,G$ perpendicular to $E\,G$, cutting $A\,B$ in F and $C\,D$ in H. The horizontal projection of $G\,E$ is $G'\,I'$, and that of F is A', as before explained, so that the horizontal projection of $F\,G$ is $A'\,G'$; produce this indefinitely, project H up to it in H', through which point draw $C'\,D'$ parallel to $G'\,I'$, and it will be the horizontal projection of the required axis. If in this way we draw the new or describing hyperboloid externally tangent to the vertical pitch-surface, it will be internally tangent to the other, and *vice versa*. In the case of external tangency the axes are on opposite sides of the common element; but the case of internal tangency, in which they are on the same side, may be directly constructed as in Fig. 2123; which differs from Fig. 2119 only in this, that the other tangent through E to the same circle $o\,o$ is taken for the vertical projection of the required axis.

2124.

2125.



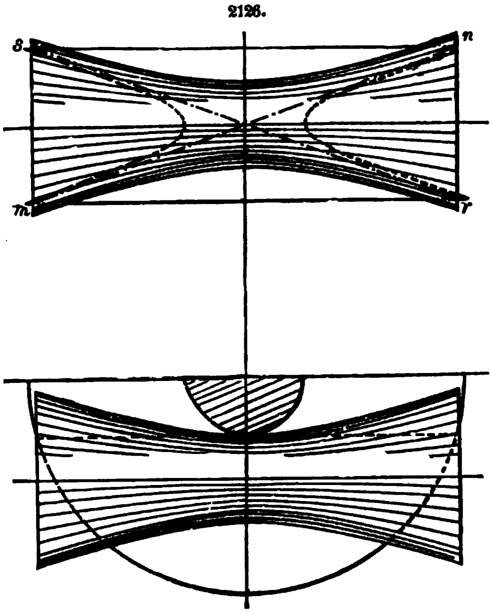
Having in this manner drawn the describing hyperboloid, we have next to find, by means of it, the tooth-surfaces. The principle of the method of doing this is illustrated in Fig. 2124. The pitch-surface is the one with the vertical axis; the large circle in the top view is the upper base, and the ellipse within it is the intersection of the inclined describing hyperboloid by the plane of that base. Were the describing surface to rotate while the other stood still, the describing line (which in this case is the element of tangency, $A'\,B'$) would always pierce the plane in some point of that ellipse. But both hyperboloids turn, and the velocity ratio is known; let then the smaller one rotate till the describing line, whose point of penetration at starting is A, pierces the plane in the point 1. The pitch-surface will meantime have turned through the known angle $A\ C\,1'$, and the curve 1–1' will have been traced on the plane of the base. So when the point of penetration reaches 2, the radius $C\,A$ will be at $C\,2'$, and the curve 2–2' will have been traced, and so on. It is to be noted that if the rotation be in the opposite direction, the curve will be different; showing that the two flanks of

the same tooth are not alike, as they may be and usually are in spur and in bevel gearing. By a process exactly similar we may determine the trace of the tooth-surface outside the pitch-hyperboloid, upon the same plane, using a describing hyperboloid externally instead of internally tangent; and it will be found that the difference between the two *faces* of the same tooth is still more marked than in the case of the flanks. These tooth-surfaces are composed of right lines, and, as in bevel-gearing, the teeth become larger as they are extended in length; but they do not converge to a point, nor yet are all the elements in the end view of the wheel tangent to the gorge-circle, nor to any other circle, as sometimes stated: the tooth-surface makes a definite trace on the gorge-plane, which ought to be determined for the sake of insuring accuracy in the drawing, if, as is most frequently the case, the frusta employed are at some distance from that plane, like either of the outer pairs in Fig. 2122. If the central pair be chosen, it will suffice to determine the trace of the tooth-surfaces on each of the end planes of the frusta; and the curvature of the meridian section being greatest at the vertex of the hyperbola, it should be carefully constructed and followed.

But if the frusta be remote from the gorge-plane, the teeth will project from a frustum limited by transverse planes, in a very unsightly manner. The fashioning of the wheel in that case is illustrated in Fig. 2125. Let $A\ B$ be the axis, $E\ D$ the generatrix, of the hyperboloid, of which $E\ F$ is the radius of the gorge, and $F\ G$ a part of the meridian section; and let $H\ G$, $K\ I$ be the planes limiting the frustum chosen. The curvature of the hyperbola diminishes so rapidly as it recedes from the vertex, that in many cases the arc $G\ I$ will not differ sensibly from a right line. If then at P, the middle point of $G\ I$, we draw a tangent to the curve, cutting $A\ B$ in C, it will in revolving describe a cone $G\ C\ H$ tangent to and practically identical with the pitch-surface within the assigned limits. The tangent may be drawn in this way: $E\ S$ is the companion generatrix (see Fig. 2120), and like $E\ D$ is an asymptote to the hyperbola. Draw through P a parallel to $E\ D$, cutting $E\ S$ in L; on $E\ S$ make $L\ M = E\ L$, and $P\ M$ will be the tangent required. Draw $G\ R$, $I\ V$ perpendicular to $P\ M$; these will be the elements of two normal cones, by which the wheel is limited, as in the case of an ordinary bevel-wheel. In this case the intersection of the describing hyperboloid with the outer normal cone should be first found, and from that, by a process analogous to those of Figs. 2114 and 2124, the tooth-outline on that cone is determined; and by a similar proceeding, that on the inner normal cone. The parts of the elements of the teeth intercepted between these two cones are so short that, as before remarked, it will be advisable also to construct the trace of the tooth-surface on the gorge-plane for the purpose of accurately fixing the positions of these elements. The process of completing the drawings of the wheel, after the outline of a tooth on each normal cone has been found, is substantially the same as in the case of bevel-wheels. Every point in either outline moves in a circle around the axis; these circles are seen as such in an end view, and as right lines in the side view, of the wheel. The tooth is therefore first drawn in the end view, the others are copied in position, and the points in the various circles thence projected to their corresponding lines in the side view.

Now, in Fig. 2125, it will be observed that the *blank* for the wheel, a portion of which is shown in outline on the left, is composed of two parts. One of these is a part of the normal cone $G\ R\ H$, the generatrix $R\ H$ being extended to O, the limit of the projecting part or face of the tooth. The other is a portion of a cone whose vertex is not C, that of the pitch-cone, as in the case of a bevel-wheel, but another point N, determined as follows: When the length of the face of the tooth has been decided on, the describing line will have a known position with relation to the axis of the pitch-surface; and by revolving around the latter, it will generate another hyperboloid. The meridian section of this being constructed, a definite arc of that hyperbola will be intercepted between $R\ O$ and $V\ W$, which like $G\ I$ will be very nearly straight. Bisect this arc, and at its middle point draw the tangent $O\ N$, which will generate the cone required. This is necessary, in order that the teeth may begin and end contact all along an element: if it be not done, the result may be that they will begin and end contact at a single point, which, sustaining all the pressure, will be rapidly abraded.

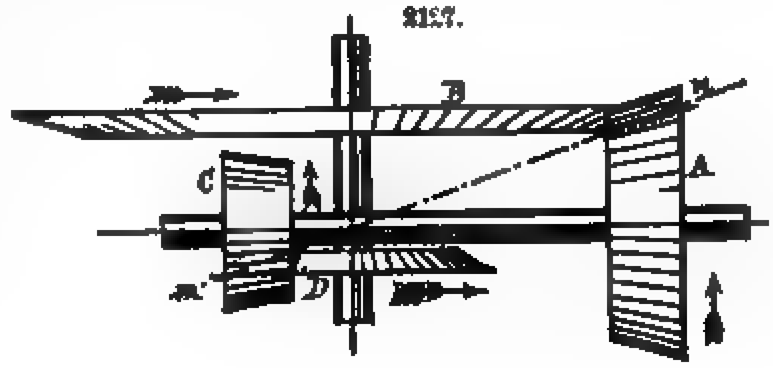
2126.



In regard to the division of the pitch-circles, the state of things at first sight appears quite contradictory. The ratio of the radii of those circles which move in contact is not the same as the velocity ratio; nor, again, is the ratio between the radii of any two pairs of circles the same. Yet it is evident that, because the velocity ratio is constant, the circles must be divided into numbers of parts having the inverse ratio of the angular velocities, and such points of subdivision will come into contact. Ordinarily, as shown in Fig. 2122, two pairs of these wheels may be used on the same

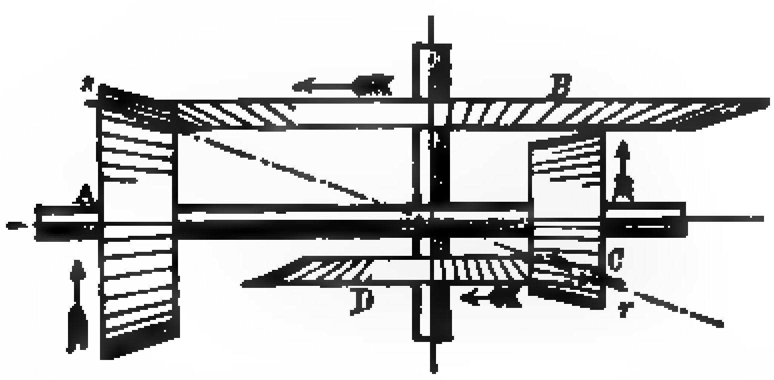
shafts, equidistant from the gorge-planes. But this is not always possible: for example, in Fig. 2126 we have two tangent hyperboloids, so situated that the projections of the axes on a plane parallel to both intersect at right angles. This case presents the remarkable feature that the two pitch-surfaces are tangent to each other along *two right lines*, $m\,n$, $r\,s$. Now from these surfaces we may cut the frusta A, B, Fig. 2127, tangent along $m\,n$; and at the same time we can make use of the smaller pair, C, D, also tangent along $m\,n$; the arrows indicating the relative directions of the rotations. Or, as in Fig. 2128, we may use frusta which are tangent along the other generatrix, $r\,s$; and A still turning in the same direction, B will turn in the opposite direction.

2127.



As with bevel-wheels, then, we may choose as to the directional relation; but evidently we cannot use, as in Fig. 2122, a double pair symmetrically situated in reference to the gorge-planes. It will practically be impossible to do this, even before reaching this condition of double tangency; for the

2128.



2129.

more nearly we approach it, the nearer will the companion generatrices, and therefore the surfaces, be to each other at any given distance from the element of tangency. Consequently the teeth will interfere with each other unless one pair be made smaller than the other, even when the axes do not have exactly the relative positions here supposed; but the smaller and more numerous the teeth, the more nearly may this limit be approached. From this consideration it follows, moreover, that the use of the central pair of wheels shown in Fig. 2122 will not always be possible, since they are in fact a double pair of frusta, the gorge-circle in each hyperboloid being the common base of the pair cut from it. Nevertheless, two wheels may be constructed, and furnished with teeth which will work together correctly, without interference, the blanks being disks whose mid-planes are the gorge-circles of Fig. 2126. And these wheels are so similar in appearance to that which would be presented by one of the class now under consideration, if furnished with teeth in the direction of one of the generatrices, that it has been stated that they belong to this class. This, however, is not the case, as may be more clearly seen from the fact that, if the central frusta can be used at all, there is no limit to their thickness, or properly speaking their length, as measured on the axes; the absurdity of which is evident from a glance at Fig. 2126. The wheels mentioned really belong to the next class of gearing; the teeth are composed of helical instead of rectilinear elements, and are constructed upon principles and in a manner totally different from the foregoing.

Screw-Gearing.

If the nut of a common screw be split lengthwise through the axis, the form of the section will be that of a rack fitting between the threads of the screw; and if the latter be turned, the rack will be driven endlong, as though it were a complete nut. If the rack is of sensible thickness, its teeth may be just such as would be obtained by splitting out of the nut a piece of the assumed thickness. The outline of the screw-thread is of no consequence; every point in it describes a helix, and since this is equally true of the nut, the male and female screws are superficially identical, and there is absolute contact over so much of the surfaces as we choose to employ. Now the rectilinear motion of the rack may be regarded as a rotation about an infinitely remote centre. If this centre be brought nearer, the rectilinear path of any point will become a circle of sensible curvature. Let us then first consider this as the pitch-circle of a spur-wheel, and construct a rack which shall gear with it. Then let us make the rack-tooth the outline of a screw-thread, the axis lying in the plane of the pitch-circle. If the screw thus formed be rotated, it will drive the wheel exactly as if the rack were moved endlong; because all the meridian sections of the screw are alike, and by construction the rack-tooth advances in the direction of the axis at a rate proportional to its angular velocity.

This is illustrated in Fig. 2129, by consideration of which it will be seen that the distance of the axis of the screw from the pitch-line of the rack is arbitrary; that is to say, the diameter of the screw may be varied without affecting the velocity ratio, which depends upon its *pitch*. This in the figure is the same as that of the teeth of the rack, forming a single-threaded screw, one turn of which rotates the wheel through an angle measured by the pitch of its teeth; and the screw may be right- or left-handed, according to the directional relation desired. We may double the pitch, forming a two-threaded screw and doubling the angular velocity of the wheel; and so we may increase the pitch and the number of threads to any desired extent, observing that the pitch of the screw

must be a *whole* number of times that of the wheel-teeth, and its diameter such as to avoid too great obliquity of action.

We have thus far supposed the wheel to be merely a thin sheet, or plane. In giving this sensible thickness, the elements of the teeth cannot be made parallel to the axis, as in a spur-wheel, but must have an inclination or rather twist, depending on the obliquity of the threads of the screw. One mode of determining this is as follows: Obviously the pitch-surface of the wheel is a cylinder, and that of the screw is another, generated by the revolution of the pitch-line of the rack about its axis; and the two are tangent at a point. If now the helix on the latter be developed on the common tangent plane, and then wrapped upon the pitch-cylinder of the wheel, it will become another helix. If the outline of the wheel-tooth be moved along this helix, parallel to itself, we shall have a twisted tooth-surface, precisely like that of Hooke's gearing. It will work correctly with the screw, to whose surface it is tangent at a point only. If the number of threads of the screw, and also its diameter, be sufficiently increased, it may be made to have the appearance of another wheel; and if the diameters of the wheel and screw in this way be made equal, they will so closely resemble each other that this combination has been called a modification of Hooke's gearing. Erroneously, however; for not only are the axes here in different planes, not only may the velocity ratio be varied without changing the diameter of either pitch-circle, but the absolute forms of the teeth of the two wheels are different, and must be, in order to transmit the rotation with a perfectly constant velocity ratio by the screw-like action, which in this case is the effective means. For instance, the wheel shown in Figs. 2129 and 2131 has teeth of the involute form, the meridian section of the screw being therefore a rack with sloping teeth, and the screw itself a true oblique helicoid; and such a helicoid it will always be, whatever the diameter or number of threads: the outlines of these threads or teeth in all its transverse sections will consequently be Archimedean spirals, and not involutes. While therefore it may be that two wheels of Hooke's form, both having involute teeth, will *work* together by

2133.

2131.

the screw-like action if placed in gear with the axes in different planes, the fact remains that the velocity ratio will not be truly constant. In all screw-gearing proper, it must be kept in mind, the screw or worm, whatever its size or the number of its threads, is a *rack*, which virtually advances by

rotation, and must be capable of driving the wheel with a constant velocity ratio if it be bodily moved endlong.

But, though the velocity ratio is dependent upon the number of threads given to the screw, and not upon its diameter, yet it is clear that for any given pair of axes and velocity ratio there must be some definite ratio between the diameters of the screw and the wheel, involving less sliding than any other; and this may be found as follows: In Fig. 2130, *C D*, *A B* are the axes, *A′ E* their common perpendicular. We first proceed exactly as in Fig. 2119 to find the line seen in the front view as *E G*, in the top view as *I′ G′*. This line would, by revolving around the axes, generate two hyperboloids, which would work together with the given velocity ratio, with no sliding other than that in the direction of the common element. The radii of the gorge-circles would be *A′ I′*, *I′ E′*: taking these gorge-circles as the bases of the pitch-cylinders, we have the required proportions for the diameters of the proposed screw and wheel. For if the supposed hyperboloids were given angular velocities having any other than the assumed ratio, there would obviously be a certain amount of sliding between the surfaces, in addition to that in the direction of the common element; and these cylinders being tangent to those hyperboloids at the gorge-circles, the same is true of them. Furthermore, *E G* in the front view is the development, upon the common tangent plane of these cylinders, of the elementary tooth, or helix, upon each surface; and it will be observed that the helices formed by wrapping it upon the cylinders are both right-handed, the consequent directional relation of the rotations being indicated by the arrows. By making both helices left-handed, this relation will be reversed; and this again, it will be seen, is consistent with the derivation of the cylinders from the hyperboloids, since, as has been shown, under the conditions here assumed the latter will be tangent along the companion generatrix *X Z*, which being wrapped upon the cylinders will give us the left-handed helical element, so that the directional relation is optional.

As above stated, the tooth-surface of a wheel, all of whose transverse sections are alike, will be tangent to the surface of the screw at only one point; so that, though strength is secured by giving the wheel definite thickness, yet the action is confined to the single plane passing through the axis of the screw. But *line-contact*, instead of mere point contact, can be secured between the thread of the screw and the wheel-tooth, by constructing the latter as shown in Fig. 2131. The meridian section of the screw is determined as before, that is, by making it a rack, to gear with a wheel whose diameter is that of the pitch-circle given, as shown on the left; the rack-tooth being straight and sloping, the wheel-teeth are involutes in this section, which is the one made by the plane *A B*. From this the screw being constructed, let it be cut by any other plane, as *L O*, parallel to *A B*. This section is of the form shown on the right, in the side view of the screw; and it may be considered as a rack-tooth also. It was shown in treating of spur-gearing that, in the case of two wheels, if the tooth-outline of one be given the other may be found; and by an analogous process we can ascertain the form of the wheel-tooth which shall work correctly with this section of the screw as a rack-tooth. Any number of other parallel planes may be passed, each giving a different rack-tooth and therefore requiring a different form to be given to the wheel-tooth. We have, then, a wheel whose transverse sections are not alike, but vary with their distance from the axis of the screw. Each one, however, having its own point of contact with the screw-surface, the result is a line of contact between the screw-thread and the wheel-tooth, which line will partake more or less of the helical form. It is usual to complete the shaping of the wheel-blank by turning off its corners, as the sharp projecting points of the teeth would be weak and comparatively useless; so that it is in effect terminated by cones, as the one whose element is *C V* in the figure. In making the drawing, it will be seen that any of the parallel planes used in the construction, as *R S*, cuts the cone, if at all, in a circle; and when the wheel-tooth to work with the corresponding rack-tooth cut from the screw by the same plane has been drawn, its outlines will cut this circle in points of the visible contour of the tooth. In like manner all other points in that contour may be found, since every transverse section of the wheel-blank is circular, whether it be beyond the limit of that conical frustum or not, as for instance that by the plane *L O*.

The accurate delineation of such a wheel is undeniably tedious; but the making of the wheel itself is accomplished in a very simple way. A steel screw is first formed, and made into a cutter by providing it with proper notches; it is then set to cut the blank, the spaces between the teeth of which are first "roughed out" with an ordinary cutter. It will be seen that when the cutting is finished, the result cannot be other than the wheel above described. For the cutter, being of the form of the screw, must drive the blank correctly; it must cut away enough metal to pass, and, as it cannot cut outside of itself, it can remove no more. Every section of the screw by a plane parallel to and at a given distance from the axis is the same; consequently in every plane of the wheel parallel to *A B* there must by this operation be formed a wheel-tooth which gears correctly with the section of the screw by that plane, considered as a rack-tooth advancing by rotation. In practice, it is necessary to take more than one cut, and after each cut to put the axes of the wheel and cutter nearer to each other. The outlines of the elementary rack-teeth and the corresponding wheel-teeth, then, should be such that this change in the position of the axes does not affect the velocity ratio; which requires that, as we have shown them, the former should be straight and sloping, the latter of the involute form. And there is this further practical advantage in this fact, that the cutter and the finished screw are more easily made in this way than in any other, being simply oblique helicoids, or V-threaded screws.

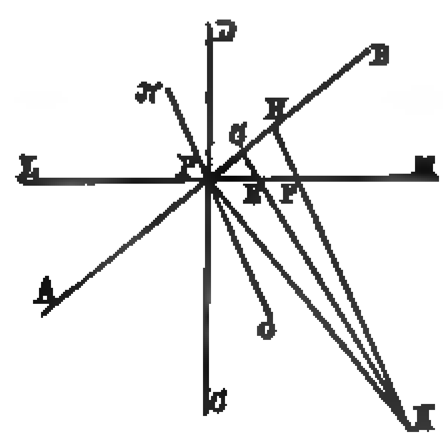
OBLIQUE SCREW-GEARING.—Thus far the axis of the screw has been supposed to lie in a plane perpendicular to that of the wheel. But, though this is the case most frequently met with, it is not at all essential that the axes should be thus situated; that of the screw may cross the plane of rotation of the wheel obliquely. As a preliminary to the construction of the teeth under that condition, it is to be noted that, though a rack usually moves in the plane of rotation of its wheel, it need not do so. It is clear that a rack may be moved in a direction parallel to the axis of the wheel, as well

as at right angles to it; and if it receive both motions at once, the rack will travel obliquely across the plane of the wheel, still working with a constant velocity ratio, as will be seen by a glance at Fig. 2132. Now a screw, in order to gear obliquely with a wheel, must act in a manner analogous to that of the rack, as is shown in Fig. 2133. *A B* is the axis of the screw, *C D* that of the wheel. In the top view we have shown simply the pitch-cylinders, with an elementary helix upon that of the screw. . Let us now suppose a thread to be formed upon it, and cut at its lowest points, *a*, *a'*, by planes perpendicular to the axis of the wheel. These sections will be similar; and in advancing from the position *a* to the position *a*, it is clear that, in order to maintain a constant velocity ratio, this section of the thread must always be acting against a section of the wheel by a plane perpendicular to its axis; and all these sections must be alike, as shown at *e*, *e'*, and of such form as to work with *a* considered as a rack-tooth; for it makes no difference whether *a* be moved to *a'* by bodily pushing the screw in the direction of its axis or by turning it.

In practically laying out the teeth and thread, it will be found most convenient to draw the pitch-cylinders as in Fig. 2134, the elementary helix being shown as passing through their point of contact *P*. Then we may assume the form of the section of the screw-thread by *L M*, the mid-plane of the wheel, thus forming our rack-tooth *a b*, and determine the outline of the wheel-tooth. The position of every point in the outline of the rack-tooth with respect to the axis of the screw being known, the helices described by these points may be drawn and the meridian section of the screw ascertained. In the figure it will be observed that the sides of the rack-tooth are straight and sloping, the teeth of the wheel being therefore involutes. But the two sides of the rack-tooth are not similarly situated in relation to the axis, and in consequence the meridian outline of the screw-thread will not be symmetrical, nor will it be bounded by right lines. Nevertheless, since its *acting* sections possess the property, before mentioned, of admitting a change in the distance between the axes without affecting the velocity ratio, it is necessary that the screw should be formed as above explained if it is required to cut its own wheel with absolute precision. The determination of its form involves some

2134.

2135.



labor; but a converse difficulty of equal if not greater magnitude is encountered if we reverse the process: for if the meridian section of the screw be assumed, we have to determine the form of a wheel-tooth which shall work with an oblique section of the thread as a rack-tooth; and this also will result in a non-symmetrical outline, the fronts and backs of the tooth being different, if the screw-thread be symmetrical in the first place. The wheel, then, having all its transverse sections alike, is similar to one of those used in Hooke's gearing, its teeth having a twist dependent on the obliquity of the screw. And in relation to this, it will be noted that the pitch of the screw is not, as in the case at first considered, either equal to or necessarily an exact multiple of that of the wheel-teeth.

The elementary helices on the two pitch-cylinders must evidently coincide when developed on the common tangent plane; and the mode of determining the pitch of the screw, and also that of the wheel-helix, when the pitch of the wheel-teeth is given, is shown in Fig. 2135. *A B* is the axis of the screw, *C D* that of the wheel, *P* the point of contact of the pitch-surfaces, and *L M* the plane of rotation of the wheel, all as in Fig. 2134, both axes and the common tangent plane being parallel to the paper. Let *P E* be the developed pitch of the wheel-teeth; then make *P K*, perpendicular to *A B*, equal to the circumference of the pitch-cylinder of the screw; draw *K E*, produce it to cut *A B* in *G*, and *P G* is the pitch; the screw then is single-threaded, one rotation advancing the wheel through an angle measured by its pitch. If it be desired to make the screw two-threaded, and thus to double the angular velocity of the wheel, it will not do to double the pitch thus found, as in the case of the ordinary worm and wheel: we must set off *P F* equal to twice the developed pitch of the wheel-teeth, draw *K F*, and produce it to cut *A B* in *H*, giving *P H* as the pitch of the screw; and so on if any other angular velocity is to be given to the wheel. The lines corresponding to *P K*, *G K* are drawn in Fig. 2133, which will make the application of this construction clear: a line *N O*, drawn through *P* parallel to *G K*, as shown also in Fig. 2134, is evidently the development and common tangent of the elementary helices on both pitch-cylinders which pass through their point of contact.

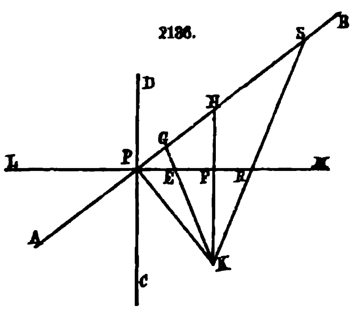
The construction explained in connection with Fig. 2130, in relation to the ordinary worm and wheel, is also true in the case of oblique screw-gearing. That is to say, if the axes and velocity ratic

be given, the screw and wheel which will work with the least sliding are determined by first constructing the rolling hyperboloids which satisfy the assigned conditions, and then taking as the pitch-surfaces the cylinders tangent at their gorge-circles; the common element of the hyperboloids being also taken as the development and common tangent of the elementary helices. Those hyperboloids in this case having but one line of tangency, the directional relation of the rotations is thereby fixed; the helix of the screw cannot be made right-handed or left-handed at option, as in Fig. 2130.

Again, it was seen that when the axis of the screw lies in the plane of rotation of the wheel, both helices must be either right-handed or left-handed. But when it crosses that plane obliquely, it will be seen from Fig. 2136 that this is not always the case. *A B*, *C D*, *L M*, *P K* being the same as in Fig. 2135, let *P E*, *P F*, *P R* be respectively once, twice, and thrice the developed wheel-pitch; then *P G*, *P H*, *P S* are the pitches of a single-, a double-, and a treble-threaded screw. Recollecting that *G K*, *H K*, and *S K* touch the screw-cylinder on its lower side, it will be seen that all the screw-helices will be right-handed. But as these lines touch the wheel-cylinder on its upper side, it will also be seen that when *S K* is wrapped upon that cylinder it will form a right-handed helix, while *G K* will form a left-handed one. The proportions in this illustrative diagram are such that *H K* is parallel to *C D*; it therefore will form no helix at all, but the wheel will be simply a common spur-wheel, the elements of the tooth-surfaces being parallel to the axis.

From the mode of generation, it is clear that the action will be confined to the plane passing through the axis of the screw and the common perpendicular of the two axes, represented by *A B* in Figs. 2133, 2134, and 2137, each section of the screw-thread by that plane, on the side which is in gear with the wheel, touching the tooth of the latter in a point whose distance from the pitch-

2136.



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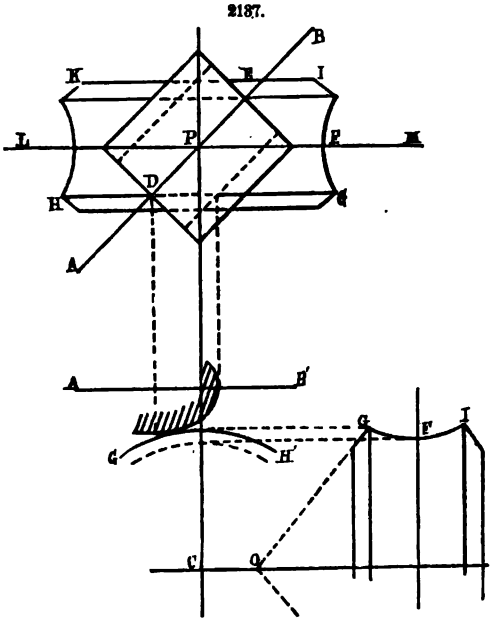

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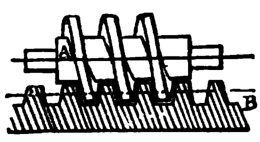


surfaces is determined by the construction of the rack and wheel in Fig. 2134. Consequently the greatest length of the screw, as in the ordinary worm and wheel, is determined by the distance through which the teeth of the elementary rack travel while actually in gear with those of the wheel. This being ascertained and set off as *D E* on the axis *A B*, Fig. 2137, the screw-blank is terminated by planes through *D* and *E* perpendicular to *A B*, the outer cylinder being shown in full lines, and the inner one, or *core* of the screw, being dotted.

The thickness of the wheel may be determined thus: Through *D* and *E* pass planes *G H*, *I K*, perpendicular to the axis; these may limit the teeth of the wheel at their tops, since any further extension in the direction of the axis would be useless. The wheel-blank need not be cylindrical, but may have the form shown, which is thus determined: The radius *P F*, obviously, will be the distance from the axis of the wheel to the outside of the core of the screw-blank, measured on the common perpendicular, minus whatever may be allowed for clearance. The plane *G D H* cuts that core in an ellipse, of which a part is shown in section in the front view, where *A′ B′* is the axis of the screw, *C* that of the wheel, whose section by this plane is the circle *G′ H′*, which must evidently clear the elliptical section. And by a like proceeding with other transverse planes, we may determine as many points as are necessary in the curve *G F I*, which practically may be made a circular arc. Drawing at *G* and *I* lines normal to this curve, the wheel-blank is terminated, as in Fig. 2137, by short conical frusta. The tooth-surfaces are, of course, not affected by this departure from the cylindrical outline, their transverse sections remaining the same; the depths of the teeth, merely, increase as they recede from the mid-plane *L M*.

Oblique Screw and Rack.—Let A, Fig. 2138, be a common V-threaded screw, whose axis is parallel to the paper. If we suppose this screw to be moved, without rotating, in a direction perpendicular to the paper, through some plastic material, the result would be the formation of a rack, B, whose teeth are composed of parallel elements, which touch the screw at points of its visible contour. If the screw now remain stationary, but free to rotate, we can move the rack perpendicularly to the paper without turning the screw, or it may be driven endlong by the rotation of the screw, or it may receive both motions at once. In the latter case the resultant is an oblique travel of the rack across the plane of rotation, as in Fig. 2132; and the degree of obliquity is entirely arbitrary, so long as it is not so great as to prevent the screw from driving the rack. We have taken the V-threaded screw, and supposed the rack-teeth to be perpendicular to the paper, only for the sake of simplicity in illustration. Evidently the same may be done with a screw of any reasonable meridian section, and in all cases there is a *line* of contact between each thread of the screw and its rack-tooth.

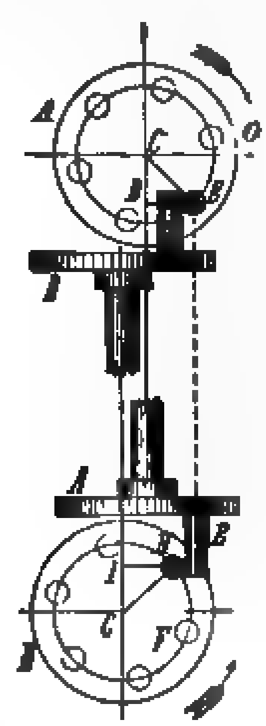
But again, the screw need not be moved in the direction above supposed in generating the rack, nor is it the best direction. This will be seen from Fig. 2139, in which A is the outer cylinder or blank of the screw, upon which the helix is shown; B is that plane section of the rack which is parallel to the elements of its own teeth and tangent to the cylinder A. Now let us suppose that the rack is to be driven by the screw as indicated by the arrows. Then, if the screw be formed into a cutter, the spaces in the rack being "roughed out" as usual, it is clear that the rack will be driven by the cutter as it works, and in one revolution it will be driven just far enough for the cutter to clear itself. In doing this, it is also clear that the helix shown, its point of contact advancing in one turn from P to G, must, in order to remove the least metal, trace upon the plane B a line which will be always tangent to the helix. Draw, then, $P\,K$ perpendicular to $C\,D$ and equal to the circumference of the cylinder, and $G\,K$ will be the direction of the teeth of the rack, which latter will travel through the distance $P\,E$ at each revolution of the screw. The form then of the rack-teeth will be determined by simply making a drawing of the screw as seen from the direction $K\,G$, the outlines of their normal sections being those of the visible spaces between the adjacent threads, and all the elements necessarily parallel to $G\,K$. If the size of the screw-blank, and the pitch $P\,E$ of the rack in the direction of its travel, be given, we may by a converse operation determine the pitch of the screw. Drawing $P\,K$ as before, set off $P\,E$; then draw $K\,E$ and produce it to cut $C\,D$ in G, thus giving $P\,G$, the required pitch.

FACE-GEARING.

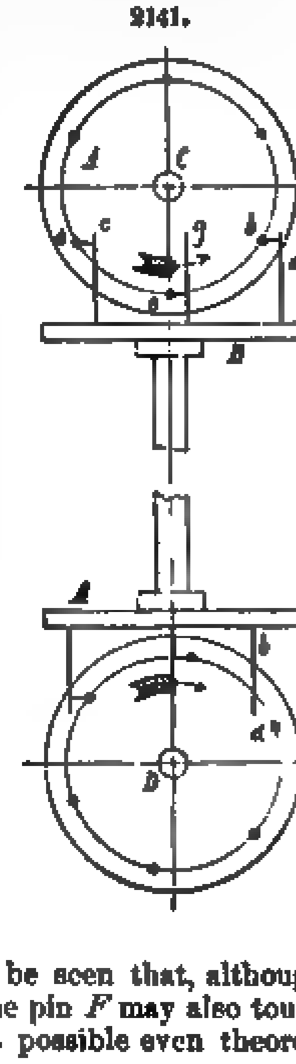
This form of gearing was formerly much used in wooden mill-work, but is now seldom met with in heavy machinery, bevel-gearing being used instead. The latter has the advantage that the teeth are in contact along a line, thus distributing the pressure and the wear over a considerable surface during the action; whereas in the former the teeth touch each other in a single point only, so that during the whole action the wear is confined to a mere line joining the successive points of tangency. Yet in light mechanism the facility of forming the teeth in the lathe may make it desirable to employ this form of gearing. The name is derived from the fact that the turned pins forming the teeth are often set in the faces of circular disks, as in Fig. 2140. In this case the teeth are cylindrical pins,

2139.

2140.



2141.

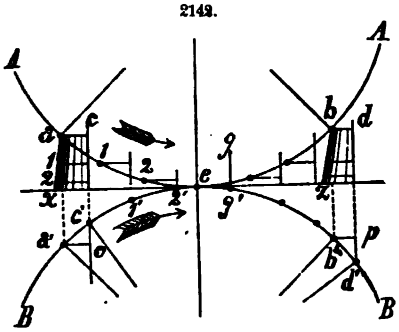


and the two wheels are exactly alike in every particular. The axes are not in the same plane, but situated like those of the common worm and wheel; that is to say, their projections upon a plane parallel to both intersect at right angles, and the length of their common perpendicular is equal to the diameter of the pins. Under these circumstances it is clear that the angle $D\,C\,E$ will always be equal to the angle $I\,G\,H$, so long as the pin E of the wheel A is in contact with the pin H of the wheel B. The velocity ratio is therefore perfectly constant. It will be noted that, the arrows indicating the directions of the rotations, the length of the pin E must be such that the next pin F of the other wheel B shall not catch upon its end in going into gear. And it will also be seen that, although at the instant of coming into contact with the next pin O of the driver A, the pin F may also touch the pin E on the back, it cannot continue to do so. That is to say, it is not possible even theoretically to secure entire freedom from backlash.

The maximum length of one pin having been determined, it is of course the same for all; and it is next to be observed, that if the number be increased, this length must be diminished; also, that in every case there will be a limit beyond which the number cannot be increased without also diminishing the diameter, and in consequence the distance between the axes. It therefore follows that ultimately the axes will intersect at right angles, and the pins will become consecutive points in the circumferences of two equal circles rolling together like the bases of the pitch-cones of a pair of mitre-wheels. In other words, as stated in the synopsis at the beginning of this article, there are no pitch *surfaces*, these degenerating into *lines*, and the elementary teeth into points. But if we suppose the axes to intersect at right angles, cylindrical pins may yet be used on one wheel, and a constant velocity ratio maintained by making the teeth of the other in the form of surfaces of revolution, if the meridian outline of the latter be correctly determined. The manner in which this outline is to be ascertained will be understood by the aid of Fig. 2141, where the two wheels, *A* and *B*, are of the same diameter. Let *a* be a pin of no sensible diameter in the wheel *A*, and *c* another in the wheel *B*, the distance *a c* between them being arbitrary. Let the wheels now turn as shown by the arrows, with a constant velocity ratio; then, when *a* reaches *e*, *c* will have gone to *g*, the arcs *a e* and *c g* being equal. The distance between the pins in the two wheels is now changed; *e g* is greater than *a c*, and it is also lower, that is, nearer to the face of *B*. The relative positions of the pins may in a similar manner be obtained in any number of intermediate positions; and it will be seen that if the vertical line *c* be taken as the axis of a surface of revolution, the radii of whose sections are the perpendiculars from *a* upon *c* in those intermediate positions, we shall have the form of a pin or tooth for *B*, such that it will be driven by a pin in *A*, of no sensible diameter, from *c* to *g* with a constant velocity ratio. If we now suppose *a* to move from *e* to *b*, this tooth will be driven from *g* to *d*; and by repeating the above process we may find the meridian outline required to maintain a constant velocity ratio during that part of the action.

This process is illustrated more fully in Fig. 2142, in which only the pitch-circles are shown, and for convenience these are made tangent at *e*. When the pin *a* occupies the positions 1, 2, the axis *c* will be at 1′, 2′; by the aid of which, as above explained, the outline *a x* is obtained, as that of a

2142.



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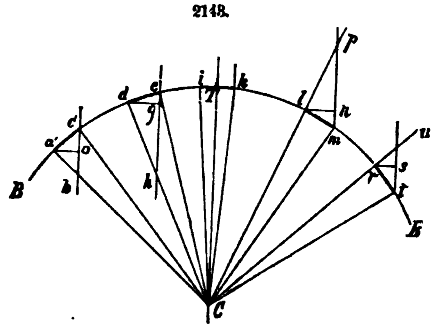
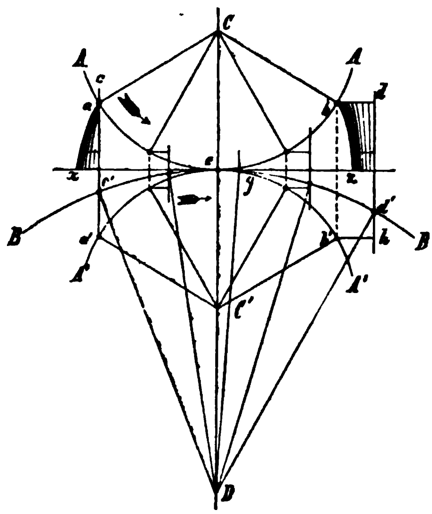


tooth which will be correctly driven by *a* through the arc *c′ g′*, which is equal to *a e*. In going from *e* to *b*, the pin must drive the tooth to *d′*; and that the velocity ratio may be constant, the outline must be that of the curve *b z*.

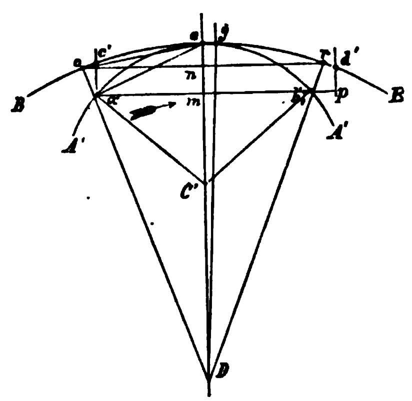
It will be observed that, the points *a*, *b* being projected to *a′*, *b′* upon the circle *B B*, which is equal to *A A*, we have the equal arcs *a′ c′*, *b′ d′*, subtending equal angles at the centre of *B B*, the radii of the upper bases of the teeth on the left and right hands respectively being therefore equal to *a′ o*, *b′ p*. Now, in Fig. 2143, let *C* be the centre of the circle *B B*, and let *a′*, *c′*, and *o* correspond to the points similarly lettered in Fig. 2142. Let *d e* be a chord equal to *a′ c′*, but nearer to the vertical line *C T*, to which *c′ b*, *e h* are parallel, and draw *d g* perpendicular to *e h*. Then, in the triangles *b a′ c′*, *h d e*, we have the angle at *a′* equal to the angle at *d*, also $a'\,c' = d\,e$, but the angle at *h* less than the angle at *b*. Consequently *d g* is greater than *a′ o*; that is to say, referring to Fig. 2142, the radius of the tooth will increase from *a* toward *x*, the maximum being reached when *a′ c′* has the position *i k* in Fig. 2143, being then bisected by the plane of the axes. And in a similar manner it may be shown that during the receding action the radius of the tooth will diminish as it recedes from the plane of centres, or in other words from *z* toward *b* in Fig. 2142; as will be seen by comparing the triangles *l m p*, *r t u*, in which $l\,m = r\,t$, the angle at *r* is equal to the angle at *l*, but the angle at *p* is less than the angle at *u*, whence *l n* is greater than *r s*. Now, in Fig. 2143, let *a′* and *r* be equidistant from *T*: then in the triangles *b a′ c′*, *r t u*, we have $a'\,c' = r\,t$; also $t\,u\,r = u\,C\,T = a'\,b\,c'$. But *b a′ c′*, which is equal to *C r t*, is less than 90°, whence *t r u* is greater than 90°. Therefore *a o* is greater than *r s*; and the same being true for other points equidistant from *T*, it follows than in Fig. 2142 all the radii of the tooth *a x*, except the lowest one, are greater than those of the tooth *b z*. The consequence of this is that, since the teeth are to be turned in the lathe, the smaller outline must be selected; and in order to secure receding instead of approaching action, the cylindrical pins must be given to the driver, and those of the form above discussed to the follower. In giving sensible diameter to the former, a change is of course made in the elementary form of the latter. A process is here pursued analogous to that employed in the case of the pin-wheels described in the section on spur-gearing; that is, a series of circular arcs are described whose centres are in the elementary outline *b z*, with the radius assumed as that of the pin; the curve tangent to those arcs is the meridian outline of the actual tooth.

But it is not necessary that the diameters of the pitch-circles shall be equal. In Fig. 2144, $B B$ is the larger, the cylindrical pins being given to $A A$, whose centre is C. The mode of constructing the curves $a x$, $b z$ is precisely the same as in Fig. 2142; and the lettering of the two figures being made as far as possible to correspond, it can be readily traced, the arcs $a e$, $e b$ being respectively equal to the arcs $c' g$, $g d'$. The positions of the points a, e, b, and the intermediate ones, on the circle $A A$, with relation to the assumed axis $c c'$ in its progress to $d d'$, are evidently precisely the same as those of the corresponding points on the equal circle $A' A'$, whose centre is c'; the latter serving better to point out the peculiarities due to the change in the relative diameters of the pitch-circles $A A$ and $B B$. These will be clear by the aid of Fig. 2145, in which D is the centre of the circle $B B$, C' that of the circle $A' A'$, the two being tangent at e. Let the arcs $e o$, $e a'$ be equal, and of any length less than 90° on either circle; and let $e r$, $e b'$ be respectively equal to them, making $a' m b'$, $o n r$ perpendicular to $e C' D$. Then, because the arcs $e o$, $e a'$ are equal, the chord $a' e$ is less than the chord $o e$, and $a' m$ is less than $o n$. Therefore, drawing through a' a parallel to $e C' D$, it will cut the arc $o e$ in some point c'. The linear velocities of the circumferences being equal, when a' has reached e, c' will be found at g, $e g$ being equal to $o c'$; and when a' reaches b', c' will be at d', $r d'$ being also equal to $o c'$. Draw through d' another parallel to $e C' D$, and prolong $a' b'$ to meet it in p. We then perceive that, whatever the lengths of the arcs $e o$, $e a'$, the distance $a' m$ is always less than $a n$, and the longer the arcs the greater this difference, which is equal to that between $n r$ and $m b'$; and that as d' always lies beyond r, $b' p$ will always be greater than this difference. Now, if, as in Fig. 2144, we assume $a' c'$ as the axis of a tooth of $B B$, to work with a cylindrical pin at a in $A A$, of no sensible diameter, that tooth will be pointed as shown, the curve $a x$ being suited for the arc of approaching action $a e$, if $A A$ drive as shown by the arrows,

2144.



2145.



which are here made to correspond with Fig. 2142. The tooth $b z$, for the arc of receding action, has however at the point b a radius equal to $b' p$. Since, when the teeth are turned in the lathe, the smallest must be used, it follows that under these conditions the curve $a x$ must be employed in determining the meridian outline of the working tooth, and that in order to secure receding instead of approaching action the cylindrical pins must be given to the follower.

If the diameter of $B B$ be increased, its curvature will diminish, and at the limit will disappear, the circle becoming the tangent to $A A$. The curves $a x$ and $b z$ will then evidently be equal and similar, each being the cycloid of which $A A$ is the generating circle; and we have the case of a rack driving a pin-wheel. There is in fact a close analogy between the form of gearing now under consideration and that already described as pin-wheel gearing; for if in face-gearing we suppose the axes to be parallel, the teeth will be turned pins placed radially in the convex surface of a cylinder, and their outlines precisely the same as those of a spur-wheel, the cylindrical pins being the same in both cases.

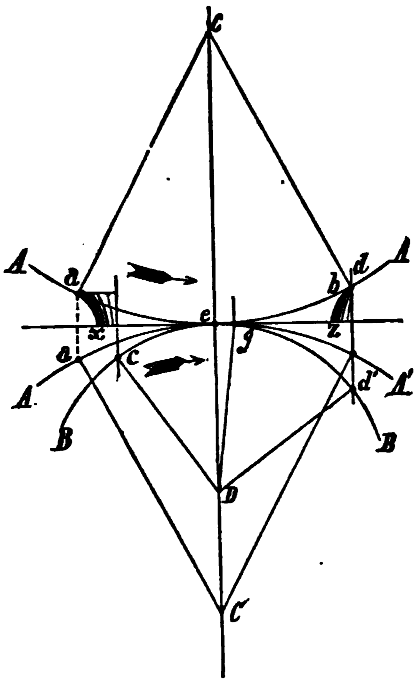
When the cylindrical pins are given to the larger of two wheels whose axes meet at right angles, as in Fig. 2146, the case, as will be seen by comparing this diagram with Fig. 2144, is nearly the converse of the previous one. The rotations being still in the same direction, the pointed tooth appears on the opposite side of the plane of the axes, and the cylindrical pins must drive, in order to secure receding action. It will be observed that, as the diameter of $A A$ is increased, the shorter will the teeth of $B B$ become for a given arc of action; and this diameter cannot be indefinitely increased, since at the limit the axes of the cylindrical pins will lie in the plane of rotation of $B B$. Still the pin-rack may be made to work, by placing the pins perpendicular to that plane, and making the axes of the teeth of $B B$ radial, the outlines being involutes of the pitch-circle; but in that case the wheel must drive, as already explained in treating of spur-gearing.

A process similar to those above described may also be employed when the axes are situated as in

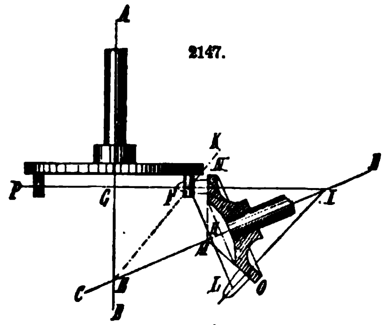
Figs. 2140 and 2141, although the diameters of the wheels are unequal, and the forms of teeth for one ascertained which will gear correctly with cylindrical pins on the other; and that even when the common perpendicular of the axes is greater than the diameter of the pins. But neither the distance between the axes nor the difference between the diameters of the wheels can be varied, except within quite narrow limits, when the axes thus lie in different planes.

It is not necessary, however, that the pins or teeth of gearing of this form should be inserted into plane surfaces; of which the suggestion above made in regard to the pin-rack is an illustration,

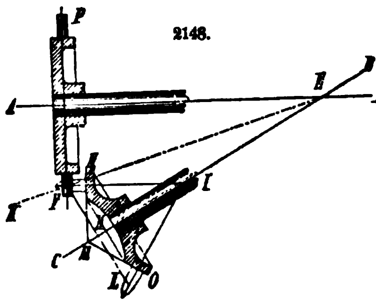
2146.



2147.

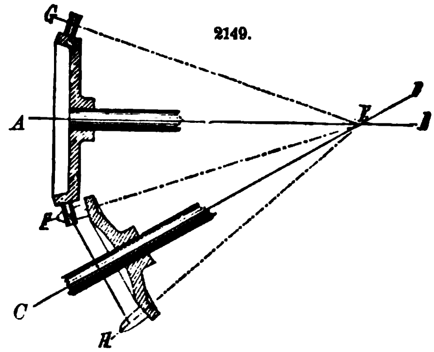


2148.



since the radial teeth of the driving wheel would be fixed in the periphery of a cylinder. But if, as shown in Fig. 2147, the axes intersect at any angle, we may proceed as follows: Draw *E K*, dividing the angle *A E D* according to the velocity ratio assigned, precisely as in bevel-gearing. Supposing that cylindrical pins are to be given to the wheel with the vertical axis, draw through any point *F* of *E K* a parallel to *A B*, as the axis of such a pin; also through *F* draw *F G* perpendicular to *A B*, and produce it to meet the other axis *C D* in the point *I*: then *F I* in revolving around *C D* will generate the cone *F I L*. The teeth of the inclined wheel are to be solids of revolution, whose axes will evidently be elements of this cone, and they may be fixed in the surface of another cone *N M O*, normal to *F I L*. A pin of the vertical wheel is shown at *F* in contact with such a tooth, of which the form may be thus determined: First let the cylindrical pin be supposed of no sensible diameter; then, if the vertical wheel be turned through any angle, the inclined one will be driven through an angle which is known, since the circumferential velocities of the circles whose radii are *F G*, *F H* must be equal. Consequently, the relative positions of the axes of the cylindrical pin and of the required tooth may be determined at any phase of the action, and their common perpendicular found. Having repeated this process a sufficient number of times, these common perpendiculars will evidently be the radii of the transverse sections of the required tooth to work with a pin of no sensible diameter, from which the meridian section may be constructed, and from it the outline of a working tooth derived in the usual manner by assigning any diameter at pleasure to the cylindrical pin.

2149.



This arrangement may also be modified as in Fig. 2148, the cylindrical pins being fixed in the periphery of a cylinder, from which they project radially; the construction of the tooth of the other wheel being made exactly as in the previous case. And it is hardly necessary to remark that in

either modification the cylindrical pins may be assigned to the conical wheel and teeth constructed for the other.

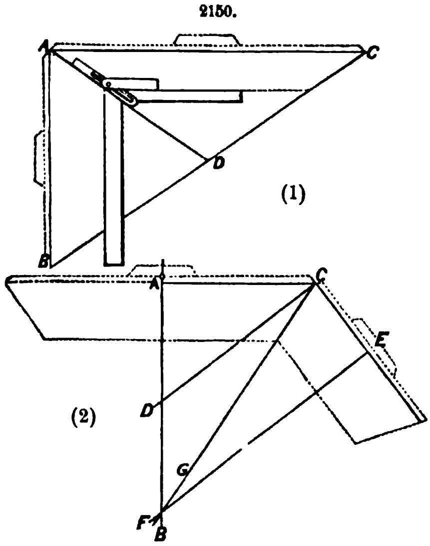
And finally, the same principles and methods may be applied to the construction of what may be called bevel-face gearing, as shown in Fig. 2149. In this case the action is exactly the same as that of two rolling cones, the axes of the teeth in one wheel being rectilinear elements of one, while the pins in the other project normally from the pitch-cone. C. W. MacC.

GEARING, FRICTIONAL. As used in the lumbering regions in this country to transmit motion in wood-working machinery, frictional gearing usually consists of smooth-surfaced wheels in contact, one pulley being made of iron, the other of wood or iron covered with wood. Where it is practicable, the wooden pulley drives the iron, wear of the former being thus saved. For driving heavy machinery, the wooden drivers are put upon the engine-shaft, and each machine is driven by a separate countershaft. Two or more of these countershafts are usually driven by contact from the same wheel. For small machinery the friction-drivers are put upon a line-shaft so as to drive a small countershaft, whence power is taken by a belt. For the wooden pulley, basswood, cottonwood, and even white pine, have given good results in driving light machinery. For heavy work, where from 40 to 60 horse-power is transmitted by simple contact, soft maple is preferable. For very small pulleys, leather and rubber may be employed. Paper pulleys have yielded excellent results.

All large drivers, say from 4 to 10 feet in diameter and from 12 to 30 inches face, should have rims of soft maple 6 or 7 inches deep. These should be made up of plank 1¼ to 2 inches thick, cut into "cants" one-sixth, one-eighth, or one-tenth of a circle, so as to place the grain of the wood as nearly as practicable in the direction of the circumference. The cants should be closely fitted, put together with white lead or glue, and strongly nailed and bolted. The wooden rim should be made up to within about 3 inches of the width of the finished pulley, and be mounted on one or two heavy iron "spiders" with 6 or 8 radial arms. For pulleys above 6 feet in diameter, there should be 8 arms, and 2 spiders when the width of face is more than 18 inches. Upon the ends of the arms are flat "pads," which should be of just sufficient width to extend across the inner face of the wooden rim as described—that is, 3 inches less than the width of the finished pulley. These pads are gained into the inner side of the rim, the gains being cut large enough to admit keys under and beside the pads. When the keys are well driven, strong lag-screws are put through the arm into the rim. This done, an additional round is put on each side of the rim to cover the bolt-heads and secure the keys from working out. The pulley is now put in its place on the shaft and keyed, the edges trued up, and the face turned off with the utmost exactness. For small drivers, the best construction is to make an iron pulley of about 8 inches less diameter and 3 inches less face than the pulley required. Have 4 lugs about an inch square cast across the face of this pulley. Make a wooden rim 4 inches deep, with face equal to that of the iron pulley, and the inside diameter equal to the outer diameter of the iron. Drive the rim snugly on over the rim of the iron pulley, having cut gains to receive the lugs, together with a hard-wood key beside each. Now add a round of cants upon each side, with their inner diameter less than the first, so as to cover the iron rim. The wood should be thoroughly seasoned, and the fibre should be in a line with the work.

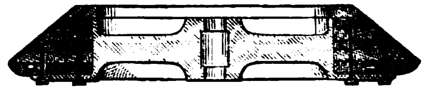
As to the width of face required in friction-gearing: When the drivers are of maple, a width of face equal to that required for a good leather belt (single) to do the same work is sufficient. (See Belting.) The driver-pulleys are similar to belt-pulleys, but much heavier. The arm should be straight, and there should be two sets of arms if the pulley is above 16 inches. A good rule is to make the thickness of rim 2¼ per cent. of the diameter. To secure accuracy, they should be fitted and turned upon the shaft and carefully balanced.

2150.



Limited experiments in order to compare frictional gearing with belted pulleys have indicated that the traction of friction-wheels is greater than that of belted pulleys, and considerably more than is usually supposed to be obtained from belts upon pulleys of either wood or iron; and that, while there is a marked falling off in the adhesion of the belt as the work increases, that of the friction augments as the labor becomes greater. Also, that the difference in the pressure required just to do the work, and that necessary to do it without slip, advances in an increasing ratio with the work of the belt; but in the friction-pulley it is almost constant throughout the whole range of experiments. Details of these tests will be found in the papers from which this abridgment is made.

2151.



Bevel Frictional Gearing.—In building this gearing, the iron cone or pulley is made similar to a bevel-pinion, except as to the teeth, instead of which there is a smoothly-turned face. In making the wooden driver, place a square across the smaller end of the finished iron pulley, and set a bevel

to it, as shown at (1) in Fig. 2150. This will give the correct bevel for the face of the driver. Next, upon any plane surface draw the lines A B and A C, making the length of A B just equal to the larger diameter of the iron pulley, and the angle at A a right angle. Then with the square and bevel draw the lines B C and A D. The distance A C is the diameter required for the driver, and the other dimensions are easily obtained.

To obtain the bevels for pulleys to work on shafts placed at acute angles, draw the lines as in (2), Fig. 2150. Let A B represent the driving-shaft. Make A C equal in length to one-half the diameter of the driving-pulley. Draw the line C D at the angle to which the shafts are to be set, and at a right angle to this line draw C E in length equal to half the diameter of the other pulley. From the point E, parallel to C D, draw E F, which will represent the other shaft. From the point of intersection of this and the line A B draw the line G C, which will give the bevels for both pulleys.

If not above 2½ feet in diameter, the driver may be built on a hub-flange, a disk of iron of about two-thirds the diameter of the pulley with a hub projecting on one side. The hub should extend half an inch beyond the thickness of the wood to receive an annular disk of smaller diameter, through which the whole may be securely bolted together. Upon the flange around the hub the pulley should be built. The first 2 or 3 inches to form the back should be of hard wood put on radially. For the remainder, use soft maple. When the wood is built up to sufficient thickness, the other flange should be put on, and the whole bolted together and turned to the exact diameter and bevel required. For a large bevel-driver it is best to use an iron centre with arms, and a flanged rim something like that of a car-wheel. The diameter of the rim or cylinder should be a few inches less than the smaller diameter of the pulley, and that of the flange something less than the larger diameter. Upon this wheel the wooden rim is built, as directed, upon the hub-flange, except that the bolts must be put in as the work progresses, so that subsequent layers will cover the heads; and the pulley is finished without the smaller flange. Fig. 2151 shows a cross-section of this pulley.

The foregoing is abridged from papers on "Frictional Gearing," by E. S. Wicklin, in the *Scientific American*, vol. xxvi., 227, *et seq.*

Grooved Frictional Gearing.—Robertson's grooved-surface frictional gearing consists of wheels or pulleys geared together by frictional contact, in which the driving surfaces are grooved or serrated annularly, the ridges of one surface entering the grooves of the other. A lateral wedging action is obtained, which augments the adhesion of the surfaces, as compared with flat friction surfaces, in the ratio of 9 to 1. That is, the grooved wheels require a force of 3 lbs. acting at their circumference to make them slip, for every 2 lbs. applied on the axis; whereas two flat surface-wheels would require (2 × 9 =) 18 lbs. of pressure on the axis to enable them to resist a force of 3 lbs. acting on the circumference. The grooves are made of V shape, for which 50° is the most suitable angle. The pitch of the grooves is varied according to the velocity and the power to be transmitted—from one-eighth to three-quarters of an inch; the ordinary pitch is three-eighths of an inch. See a paper by Mr. James Robertson on "Grooved-Surface Frictional Gearing," in "Proceedings of Institution of Mechanical Engineers," 1856.

GENEVA STOP. Where a train of wheels is set in motion by a spring inclosed in a barrel, it becomes of consequence not to over-wind the spring. The *Geneva stop*, Fig. 2152, has been contrived with the view of preventing such an occurrence, and will be found in all watches which have not a fusee. A disk A, furnished with one projecting tooth P, is fixed upon the axis of the barrel containing the mainspring, and is turned by the key of the watch. Another disk, B, shaped as in the drawing, is also fitted to the cover of the barrel, and is turned onward in one direction through a definite angle every time that the tooth P passes through one of its openings, being locked or prevented from moving at other times by the action of the convex surface of the disk A. In this manner each rotation of A will advance B through a certain space, and the motion will continue until the convex surface of A meets the convex portion E, which is allowed to remain upon the disk B in order to stop the winding up. The winding action having ceased, the disks will return to their normal positions as the mechanism runs down. Instead of supposing A to make complete revolutions, let it oscillate to and fro through somewhat more than a right angle; then B will oscillate in like manner, and will be held firmly by the opposition of the convex to the concave surface, except during the time that P is moving in the notch.

2152.

GIB AND COTTER. A method of connecting separate parts of a machine. Sometimes one of the connected pieces is required to move while the other remains stationary; frequently both pieces have motion imparted to them, as in the case of the connecting-rod of a steam-engine, when the connection at the end is often made by means of gibs, a cotter, and a strap. Again, both connected pieces may be stationary, in which case the principle of the connection is the same.

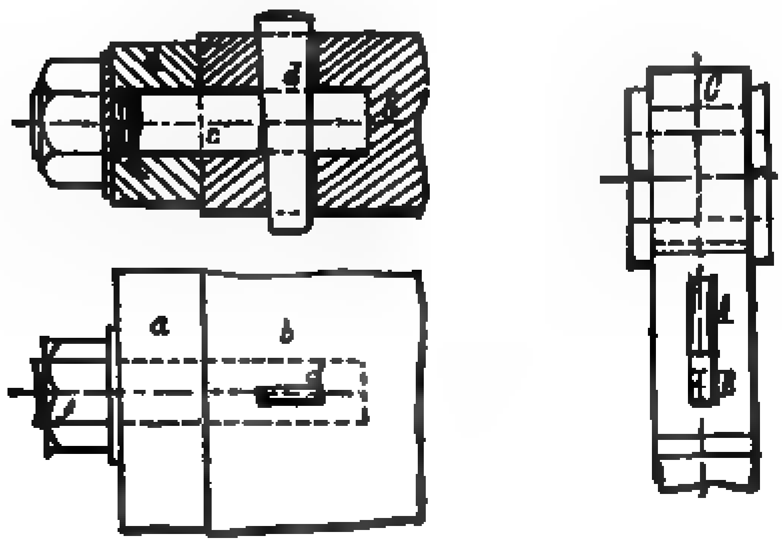
There are three forms of this device: 1. The simple cotter without gibs; 2. A cotter and one gib; 3. A cotter and two gibs. Of the second and third forms there are a variety of designs, and various means are employed to force home the cotter and to keep it there.

The cotter itself is a tapered piece of metal, generally resembling in form and action a wedge, but with this difference, that the wedge is used to force asunder parts of the same piece or different pieces, while the cotter is employed to draw together by means of available parts two or more pieces of metal. The amount of taper given to the cotter must not exceed the angle of repose of metal upon metal, which for greased surfaces may be taken at about 4°. Some authorities recommend a taper of 1 in 24 to 1 in 48 for simple cotters, and 1 in 8 to 1 in 16 when the slacking of the cotter is prevented by a screwed prolongation of the gib; a common rule is to make the taper one-half to three-fourths of an inch to each foot of length.

Cotter connecting two Pieces without a Gib.—In Fig. 2153 is shown an example of the use of a

cotter without a gib being employed in conjunction with it; it here maintains the bolt *c* in the hole made in the piece *b* to receive it. The action of the cotter is simply to wedge itself tightly into

2153.

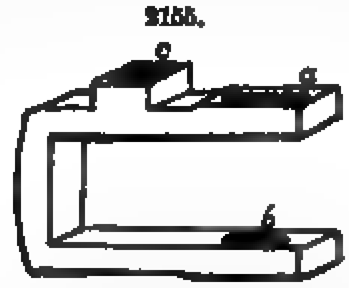


the pieces, and maintain its hold by the grip thus induced. It is quite evident that so long as *d* keeps its place the bolt *c* cannot be removed from *b*.

Cotter connecting two Pieces when one Gib is used.—Fig. 2154 gives two views of a connecting-rod. *A* is the cotter, *B* the gib, and *C* the strap. The shape of the strap is shown more clearly in Fig. 2155, *a*, *b*, and *c* being the openings in it.

Cotter and two Gibs.—Fig. 2156 shows a connecting-

2155.



rod head, held together by a strap, cotter, and two gibs; the strap is marked *s s*, the cotter *a*, and the two gibs *b* respectively. They firmly hold the brasses at the end of the rod in their places. The advantage of two gibs is, that they keep the strap firmer against the brasses. The screw which forms the lower part of the gib serves to prevent the cotter from falling or being jerked out when the engine is in motion. After the strap *s* is put on the connecting-rod, the gib *b* is inserted, and then the nut *c* is placed so that when the key *a* is put in the nut can be screwed up. The key is driven home with the hammer, the nut *c* being slackened to allow it to come down. When it is made as tight as is required, the nut *d* is put on and screwed up tightly. Then *c* is screwed down, and thus the two prevent the key from becoming slack. The hole for the bolt at *e* must be made elliptical, so as to allow the key to come down without bending the bolt.

The foregoing is abridged from "Principles of Machine Construction," Tomkins, London and Glasgow, 1878.

GIG. See Cloth-finishing Machinery.

GIN, COTTON. See Cotton-Gin.

GIN, HOISTING. See Cranes and Derricks.

GIRDERS. See Carpentry.

GLASS, MANUFACTURE OF. Glass is an amorphous substance, hard and brittle at ordinary temperatures, liquid or soft at a high heat, transparent or translucent, colored or colorless, and presenting a special fracture. It is the result of the combination of silicic acid (silex) with several of the following bases: potash, soda, lime, magnesia, oxide of lead, oxide of iron, and aluminum. The various sorts of glass are distinguished with regard to their composition, their mode of fabrication, and their uses.

Window-pane glass, *mirrors*, and *glass for table use* are formed of the same elements associated in different proportions. These elements are silex, lime, and soda.

Bohemian glass, which is used in Germany for the production of drinking-vessels, is a silicate with a potash and lime base. It contains besides, as do all other kinds of glass, a small quantity of aluminum and of oxide of iron, obtained either from the crucible in which it is melted, or from the more or less purified materials employed for its production.

Bottle-glass contains, together with the silex, soda, or potash, lime, magnesia, aluminum, and iron oxide.

Crystal is a glass having a base of lead oxide and potash. *Flint-glass*, a dense substance used for optical purposes, and *strass*, employed in imitating precious stones, are of similar elementary constitution, though the ingredients are in different proportions.

The enamels contain, in addition to the normal glass ingredients, oxide of tin or arsenious acid, which gives them the opacity that distinguishes them from all other classes of glass.

Colored glass obtains its tints, which may be infinitely varied, from various metallic oxides, from some metals, carbon, and sulphur. Many kinds of colorless glass contain a small quantity of oxide of manganese, this substance being introduced in order to obtain a whiter glass.

To these may be added the *soluble glass*, which is a simple silicate of soda or of potash, or a mixture of the two silicates.

The specific gravity of glass varies with its composition, from 2.4 to about 3.6, although optical glass of greater specific gravity is sometimes made, amounting in some instances to 5. Its density and also its refractive property are increased with the proportion of oxide of lead it contains. Brittleness is a quality that limits the alteration of the shape of glass within narrow bounds, after it has cooled; but when softened by heat while it is highly tenacious, no substance is more easily moulded into any form, and it can be blown by the breath into hollow vessels of which the substance is so thin that they may almost float in the air. It may also be rapidly drawn out into threads of several hundred feet in length; and these have been interwoven in fabrics of silk, producing a beautiful effect. In the soft plastic state it may be cut with knives and scissors like sheets of caoutchouc. It is then inelastic like wax; but when cooled its fibres on being beaten fly back with a spring, and hollow balls of the material have, when dropped on the smooth face of an anvil from the height of 10 or 12 feet, been found to rebound without fracture to one-third or one-half the same height. It has the valuable property of welding perfectly when red-hot, and portions brought together are instantly united. When moderately heated it is readily broken in any direction by the sudden contraction caused by the application of a cold body to its surface. It is also divided when cold by breaking it along lines cut to a slight depth by a diamond, or some other extremely hard-pointed body of the exact form suited for this purpose; and it may be bored with steel drills, provided these are kept slightly moistened with water, which forms a paste with the powder produced. Oil of turpentine, either alone or holding some camphor in solution, is also used for the same purpose. Copper tubes fed with emery also serve to bore holes in glass. Acids and alkalies act upon glass differently according to its composition, and reference should be made to this in storing different liquids in bottles. Silicate of alumina is readily attacked by acids, and bottles in which this is in excess are soon corroded even by the bitartrate of potash in wine, and by the reaction the liquor itself is contaminated. A glass that loses its polish by heat is sure to be attacked by acids. Oxide of lead when used in large proportion is liable to be in part reduced to a metallic state by different chemical reagents, and give a black color to the glass. All glasses are attacked by hydrofluoric acid.

Melting.—The various materials entering into glass manufacture will be noted as each class of glass is described. For melting, these are thoroughly ground, mixed together, and sifted, and are incorporated with from one-quarter to one-third their weight of broken glass before being introduced into the melting-pots. The latter are previously heated to a white heat in the furnace, and receive only two-thirds of a charge at a time, more being added as the first portion melts down. The pot being at last filled with the melted "metal," the heat is raised as rapidly as possible, and the progress of the operation is judged of by the workman dipping iron rods from time to time into the mixture and examining the appearance of the drops withdrawn. A nearly homogeneous product, which becomes transparent on cooling, indicates that the most refractory ingredients have been all dissolved. Their mixture is facilitated by the continual disengagement of carbonic acid gas, which in its escape causes the whole to be thrown into ebullition. Some of the gas remains in the mass, rendering it spongy and full of vesicles. Unless in the manufacture of the finer qualities of glass, for which the purest materials are employed, there is also a scum called "glass gall" or "sandiver" floating on the surface, consisting of the insoluble matters, and the sulphates of soda and lime not taken up by the mixture. This is removed by ladling, and the metal is next "fined," which is done by increasing the heat to the highest degree, and keeping the contents of the pots in a state of perfect fluidity for from 10 to 30 hours; in this time the bubbles disappear, and the insoluble matters settle to the bottom. The furnace is then allowed to cool until the metal has become viscid, so that it may be taken out and worked; and it is afterward kept at a sufficiently high temperature to maintain the glass in this condition, that it may be used as required. For construction of glass furnaces and pots, see FURNACES, GLASS.

Window-Glass.—The glass commonly used for window-panes is one of the hardest varieties, and is of unsuitable quality for shaping into vessels or manufacturing by cutting or grinding. The following table shows the composition of several varieties:

NAME.	Silex.	Lime.	Soda.	Potash.	Alumina.	Oxides of Iron and Manganese.	Total.
French glass	69.6	13.4	15.2	....	1.4	.4	100
Belgian glass	72.5	13.1	13	....	1	.4	100
English glass	72.9	13.2	12.4	....	1	.5	100
Very white potash glass	71.2	11.6	2.3	14.2	0.4	.3	100
Glass easily tarnished, bad quality	71.4	3.6	16.2	6.9	1	.9	100

The ingredients used are sand, sulphate of soda, and lime in the form of carbonate or slacked lime. In the north of France and in Belgium these are employed in the following proportions: white sand, 100 parts; sulphate of soda, 35 to 40; limestone, 25 to 35; coke powdered, 1.5 to 2; binoxide of manganese, 0.5; and glass scrap in variable quantity, usually in the same proportion as sand. Arsenious acid is sometimes added to act as a decolorizing agent and to facilitate the fining. English makers produce a very fine white glass for photography, and for covering pictures in frames, in

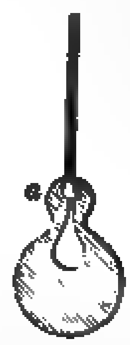
closed pots, with the following ingredients: Fontainebleau or American sand, 100 parts; carbonate of soda at 90°, 36; nitrate of soda, 5; powdered slacked lime, 12; and arsenious acid, 0.5.

There are three kinds of glass which come under the general heading of window-glass, namely, sheet, crown, and plate. All of these differ in their manufacture. Crown-glass is first blown into a globe or sphere and flattened out into a circular disk; sheet-glass is formed into a cylinder, which is opened out into a sheet; and plate-glass is cast on huge tables.

Sheet-Glass.—In the manufacture of sheet-glass two furnaces are generally used, one for melting or making the glass, and the other for reheating it during the process of blowing. The latter is usually of oblong form, with 4, 5, or 6 holes on each side for as many workmen. On each side of this furnace is a pit about 7 feet deep, 16 feet wide, and as long as the furnace; over this at intervals of about 2 feet are erected, in front of each hole of the furnace, wooden stagings or platforms, upon which the workman stands when swinging the cylinder to and fro and over his head. The manufacture may be divided into three processes: 1, blowing the cylinder; 2, flattening it out into a sheet; 3, polishing the sheet. The operation of blowing is represented in Fig. 2157, and

2157.

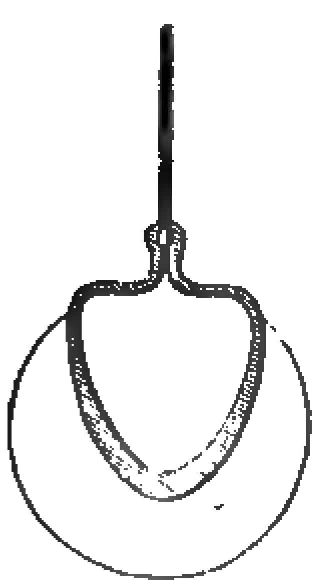
2158.



2159.

begins with the collection of a sufficient quantity of metal from the pot at the end of the pipe. A massive glass ball is thus attached round the knob of the pipe, which must be pushed forward with a *flatting-iron* until an annular groove is produced. When this operation is completed, the blower rounds the ball by rolling it on the marver, and distends it slightly by blowing. It then assumes the form represented in Fig. 2158, from which it will be seen that the mass of glass is thickest in front, as from that part it has to be distended and lengthened into a cylinder. In the subsequent operations, it first assumes the width of the future cylinder and then the length. With this object in view, the workman, after having rewarmed the ball of glass, holds it perpendicularly above his head, and blows into it. The heavy bottom, yielding with less ease to the blast, admits of the distention of the width, and a flattened bottle is formed, Fig. 2159. As soon as the proper width is attained, the pipe is quickly inverted, so that the ball is undermost, and an incessant swinging motion is then kept up with a constant blast. Further distention is thus effected, but from the bottom only, as the thinner sides have by this time cooled, and in consequence of the swinging motion in the direction of the length, so that the bottle acquires

2160.



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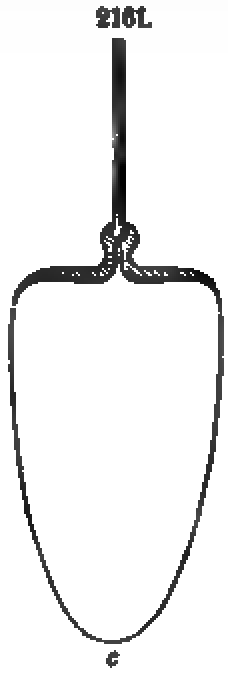

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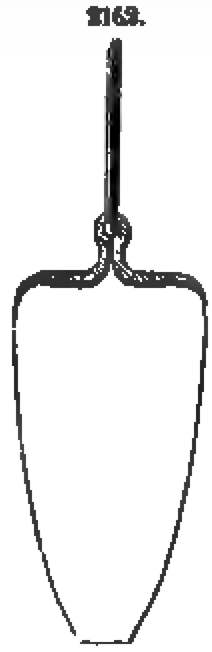

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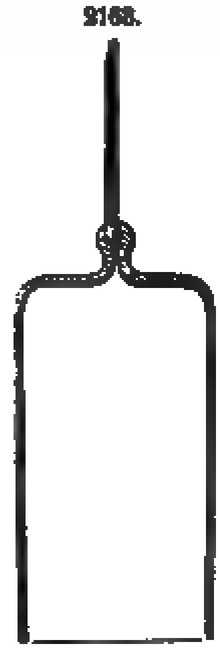


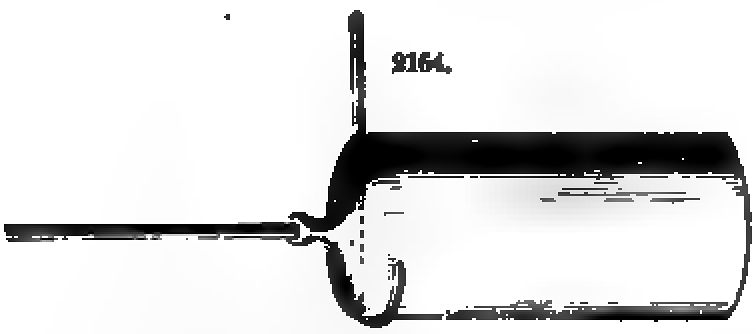
the form represented in Fig. 2160 by the time that the glass has so far cooled as to be no longer expansible. If the swinging were intermitted, the bottle would be distended in all directions, and present the form indicated by the circular line. By repeated warming, swinging, and blowing, the form Fig. 2161 is gradually produced, which is of the proper length of the cylinder. It is then conical, and terminated by a semicircle, in the middle of which, at *c*, is the thinnest part of the vessel.

When the workman blows air into the pipe, and closes the aperture with his thumb before withdrawing the pipe from his mouth, the air expands and exerts great tension upon the sides of the cylinder; if the weakest part, at *c*, is now held in the flame, it will be blown out and burst. The cylinder having thus been *opened* as represented in Fig. 2162, the next object is to extend the somewhat uneven and thick margin of the aperture, and reduce it to the proper dimensions, while at the same time the other parts are straightened and acquire a uniform diameter, as is shown in Fig. 2163. Prominent portions, which may sometimes project, are cut away with the scissors.

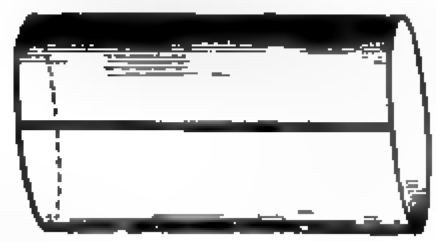
According to the size of the cylinder, it may be either blown at once, or it will require to be reheated several times. When very long and wide cylinders are blown, the lower portion is liable to become too thin; an extra portion of glass must then be incorporated with it before the opening process.

The neck and curvature where the pipe was attached to the cylinder have now to be removed, in order to spread the whole out in the form of a plate, and the cylinder must be cut open lengthwise.

2164.



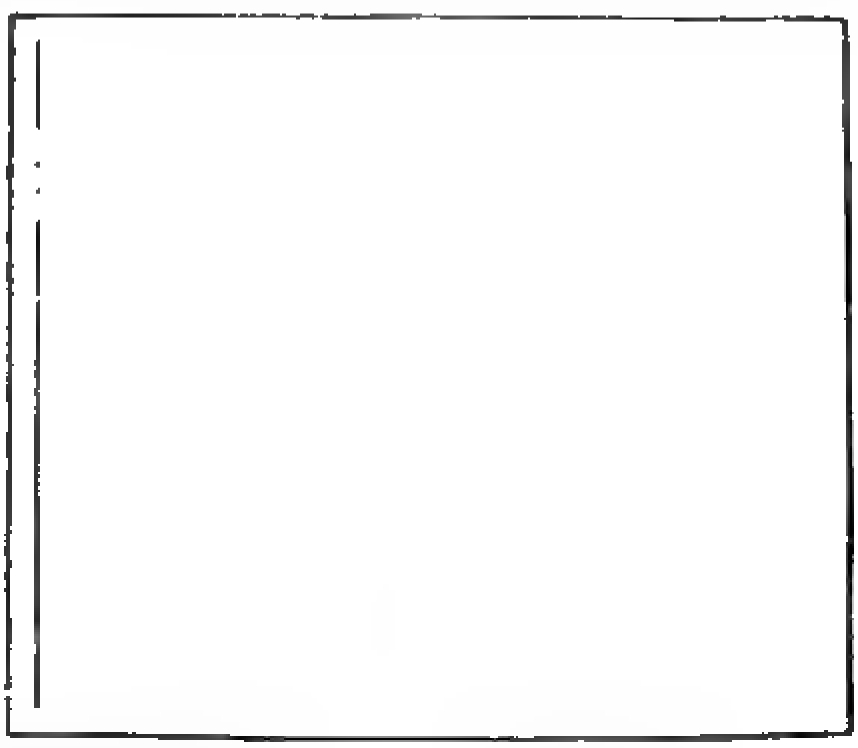
2165.



The cylinder, supported by an assistant upon a wooden rod, is therefore turned round two or three times in the curve of a bent iron, heated to redness, as shown in Fig. 2164, and a drop of water is allowed to fall upon the heated line, which fractures the glass and detaches the cap. In a similar manner, but in a straight direction, a crack is made longitudinally, and the cylinder is then prepared for spreading or *flatting*, Fig. 2165. Instead of cracking the cylinder by this means, the cap of the cylinder is sometimes taken off by winding around it a thread of hot glass, and after removing the latter applying a piece of cold iron to any point which the thread covered. After trimming the other end by cutting off about 2 inches in length with a diamond, the cylinder is split open longitudinally by drawing along its inside surface a diamond attached to a long handle and guided by a wooden rule.

Flatting is conducted in furnaces purposely constructed, the principal parts of one of which are shown in Fig. 2166. The flame first plays upon the flatting-hearth *C* before entering the annealing or cooling furnace *B*, which is also heated directly by the fire, when it escapes through the flue or channel *D*, by which the cylinders are introduced to be subsequently removed. The flattener stands in front of the aperture *l*, the workman engaged at the cooling-furnace before *m*; and an assistant pushes the cylinder *o o o o* along the railway *p*. The most essential part of the furnace, however, is the *spreading-plate* or *flatting-stone* *q* and *q'*. This must be perfectly even, without any roughness or inequalities which would scratch the glass or make it lumpy; it must be unalterable in the fire, and of a size somewhat larger than the flattened cylinders. A plate of this description is usually manufactured from fire-proof clay mixed with cement (either ground fragments of burnt clay of the same kind, or fine sand, or ground quartz), strongly beaten during drying, then burnt, and lastly ground smooth; it is laid upon a bed of sand and in contact with a second table of the same sort in the cooling-oven. To make quite sure that no injury shall be sustained by the plates upon the flatting-stone, it is customary to cover this previously with a *lager*, which is a thick plate of glass expressly blown for this purpose. These lagers are soon devitrified, which is of no moment so long as the surface remains smooth; this, however, does not last long, and frequent renewal of the lagër becomes necessary. Lastly, to prevent the cylinders from attaching themselves to the lager, the flattener, in some manufactories, throws a handful of lime into the furnace, which is carried as fine dust by the flame and spread over the lager. The temperature in the flatting-furnace must only be just sufficient to soften the cylinders, while in the cooling-furnace it must not attain that point.

2166.



The spreading operation is commenced by introducing the cylinders into the warming-tube *D*. The further the cylinders are pushed forward by those succeeding them, the more they become heated, until they begin to soften on reaching the flatting-stone. They are then taken by the workman with

a rectangular bent iron, and placed upon the lager with the cut side uppermost, where they open of themselves, and are easily straightened and made even. For this latter purpose, a rod of iron, furnished at the end with a wooden polisher, Fig. 2167, is employed, and this is dipped into water each time it is used. When all the curvatures and lumps have been reduced, the sheet is pushed backward into the annealing-oven, where it cools down and is placed in an upright leaning position. Between every 30 or 40 sheets an iron rod *s s* is inserted, and the operation is continued until the whole furnace is filled.

2167.

Fig. 2168 is an elevation of a flatting-furnace in section, with three annealing-arches of the ordinary description. Fig. 2169 is a ground plan of the same. In Fig 2170 are elevations of two end views of the flatting-furnace. *a b* is the spreading-furnace, divided into two compartments by the partition *c*; *d d* are two sets of fire-bars, on which wood must be burnt; *e* is the spreading or flatting stone of the furnace, which must be perfectly smooth and even; *i* is an opening through which

2168.

the cylinder is placed in the furnace previous to being laid on the flatting-stone *e*; *h* is the opening through which the workman spreads the cylinder into a flat sheet of glass; *f* is the opening through which the sheet of glass is removed to the table or bed *g*, in the compartment *b*. The upper side of the table *g* is made of stone, similar to that employed as the flattening surface. It is fixed to an iron framework on wheels, and is kept at a proper degree of heat by remaining in the furnace, as shown in the drawing. The carriage runs on a railway in front of the annealing-arches, where the sheet is transferred in the usual way.

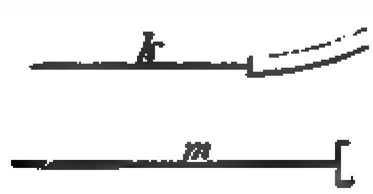
The cylinder is placed on the flatting-stone, and is split lengthwise by passing a red-hot iron bar *k* from end to end, a little charcoal powder being previously sprinkled on the inner surface of the

2169.

cylinder. It is now spread out into a sheet by pressing the same on the flatting-stone, by means of a small block of elder-wood, fixed on an iron bar *m*. The temperature at which the flatting is performed is such that the operation does not occupy more than a minute.

Two improvements have been introduced in this operation. One consists in making part of the floor of the compartment *a* to consist of a movable stone about 10 inches in diameter, on which the

2170.



cylinder is placed. It is gradually exposed on all sides to the action of the fire by causing the stone to revolve on its axis, and thus the objection to the previous plan is avoided, where one side of each cylinder became so much hotter than the other.

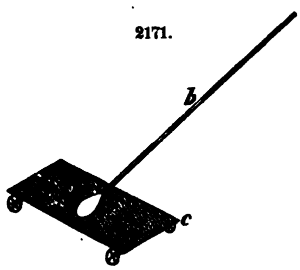
Annealing usually requires from 24 to 36 hours. From the annealing-oven the sheets are taken to the warehouse, where they are smoothed, polished, assorted, and cut into panes of the required

dimensions. The former method of grinding and polishing sheet-glass by imbedding the sheets in plaster of Paris proved inadequate to remove the defects in the glass consequent upon the mode of manufacture. The chief of these was the undulating or wavy appearance of the surface, called cockles, which was attributed to the difference of diameter between the inner and outer surfaces of the cylinder, and which caused objects seen through the glass to be distorted. Notwithstanding the glass was made very thick, after the superficial roughness was removed the result was a thin sheet much inferior to plate-glass. The ingenious process devised by Mr. James Chance for producing patent plate-glass, which is now used in England and most factories on the continent, is one of the most important improvements in the manufacture. By removing the thin outer surface of the glass by this method, an evenness and a polish are secured, even on the thinnest sheet, which make it in many respects equal to plate-glass, and far superior to the sheet-glass produced by the old process. The improved method consists in placing the sheet to be ground and polished upon a flat surface covered with a piece of damp soft leather or cotton cloth. A slight pressure applied to the glass causes it to adhere to the surface of cotton or leather, and by thus producing a vacuum the entire sheet is firmly maintained in a flat position by atmospheric pressure. The exposed surfaces of two sheets fixed in this manner are rubbed against each other in a horizontal position by machinery, emery and water being constantly supplied to keep up the friction. Both sides of the sheet are polished in this manner, with only a slight diminution of the thickness of the glass. After the removal of the sheets from these surfaces, they resume by their own elasticity their original shape, which is often more or less curved. The final polish is given to the sheets by a process similar to that used in polishing plate-glass. In each process through which the glass has passed it was exposed to some imperfection, and some of the sheets bear the peculiar defects of them all and are of little value; others are suitable for inferior uses, and but few are perfect. The wide difference between the quality of the best and the worst sheets is indicated by the fact that the former are valued at three times more than the latter. The same kind of material is used in the production of both crown- and sheet-glass. The remarkable brilliancy of surface of the former gives to it a certain advantage over sheet-glass; but the larger size easily attained in making the latter gives it the supremacy in commerce. Of crown-glass it is difficult to obtain panes of 34 × 22 inches, while the usual size of the sheets of cylinder-glass is 47 × 32 inches, and cylinders are occasionally blown 77 inches in length, requiring about 38 lbs. of glass.

Crown-Glass.—Illustrations of the furnace used for melting crown-glass will be found under FURNACES, GLASS.

When a certain weight of glass, *a*, Fig. 2171, has been collected or gathered from the pots on the end of the tube *b*, it is fashioned into a peculiar form, as shown in the figure, on a solid plate of cast-iron *c*, called a marver. Previous to the operation of "marvering," the workman cools the iron pipe, which has become heated by being exposed in the melting-furnace. The marver *c* is placed on rollers for the convenience of moving it from place to place as required. When the mass of glass has assumed the proper form, a boy blows through the iron tube, while the workman continues to roll the ball upon the marver. During the previous operation of "marvering," the mass of glass is fashioned so as to give the outer extremity a conical form, the extreme end of which becomes the outer axis of the globe during the operation of blowing. This outer axis is called the "bullion," and during the expanding of the globe the workman rolls this bullion along a straight-edge. The piece of glass, after

2171.



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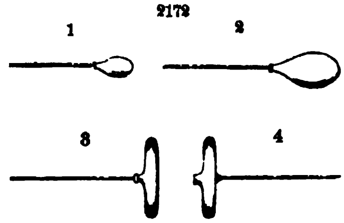
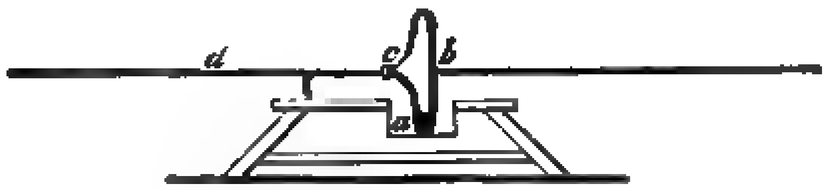


the above operation, is reheated in the blowing-furnace, and expanded by the workman blowing through the iron pipe, until it is so far cooled as to require another "heat." When it has been blown to the proper size, Fig. 2172, 2, it is again exposed to the heat of the furnace, when the workman, resting the pipe on an iron support, during which time the neck remains cool, causes the glass globe, by a peculiar motion of the pipe, to assume the shape shown at 3. This last operation is technically termed "bottoming the piece." It is then removed to a framing, Fig. 2173, where it rests on its edge on some ground charcoal and cinders *a*. Another workman then attaches a strong iron rod, with a quantity of melted glass at its end, to the centre of the piece, as at *b*. The "blower" now touches the neck of the piece at *c* with an iron rod previously dipped in water, and, by a smart blow on the iron tube *d*, detaches the piece, leaving the neck open, as shown at 4, Fig. 2172.

The "piece" is now removed to the "flashing-furnace." The thick neck is first heated at the opening, whence a powerful flame is issuing. Fuel is placed on the grating for the purpose of warming the piece, while the neck is heated from the larger furnace through an opening in the side. As soon as the neck is sufficiently soft, a boy inserts a flat iron tool through the nose-hole, to smooth the roughness left in the neck by breaking it off as described above. When the neck has been sufficiently heated at the nose-hole, the bell-shaped vessel is brought in front of another opening, where it receives the full heat of the flame, and the pipe is then made to revolve with the greatest possible

rapidity. The action of this rotary motion upon the softened glass is easily conceived. The centrifugal force communicates to the particles of glass a tendency to fly off at a tangent, and to arrange themselves in a circular plane perpendicular to the axis of rotation. The mouth, being the softest part, first expands, and this quickly enlarges until the whole suddenly opens into one sheet of glass, Fig. 2174, about 6 feet in diameter, which, with the exception of the central portion, is of nearly

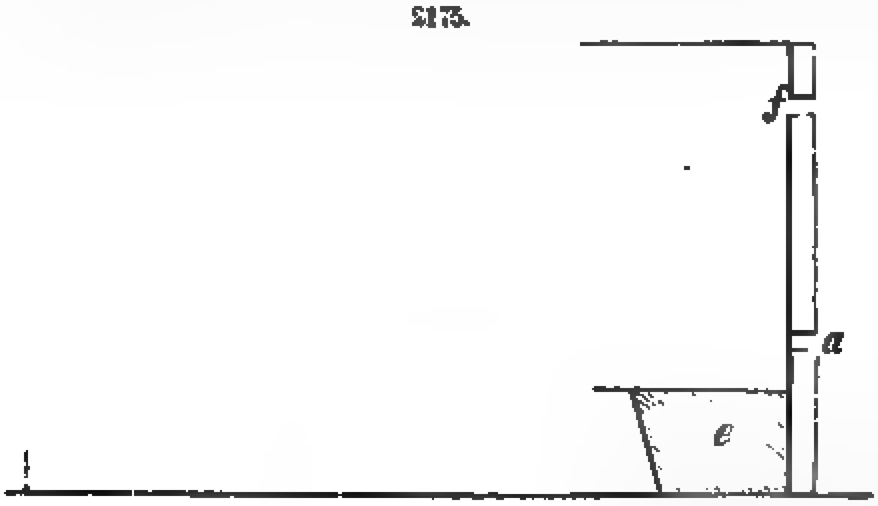
2173.



2174.

uniform thickness. It is obvious that a sheet of such dimensions must quickly fold together in the soft state, if the rotary motion is not kept up. The workman, therefore, continues the rotation after the removal of the sheet from the flame of the furnace, until it reaches the annealing-oven, where it is placed on a small circular bench, and is detached from the rod by means of a pair of strong shears, leaving a mark called the "bullion," or bull's-eye. Another workman, who has charge of the annealing, now raises the "table" of glass upon a large fork-like instrument, and carries it to an upright position in the annealing-arch, Fig. 2175. The tables stand thus on their edges, upon two strong parallel iron supports, which run the whole length of the annealing-kiln. The glass, after remaining in the kiln for a considerable time, during which the cooling has been carefully regulated, is withdrawn, so as to enable a workman to go inside and hand out each table on the outside to an assistant.

2175.



This mode of manufacture possesses at present little more than retrospective interest, despite the advantage which it offers in the brilliancy of the glass produced. To make a sheet-glass in which shall be united the brilliant qualities of crown-glass with the cheapness of cylinder-glass is one of the most important problems in glass-making which inventors have yet to solve.

Plate-Glass.—The composition of this glass is given by Peligot as follows:

MANUFACTURE.	Silex.	Lime.	Soda.	Alumina and Iron Oxide.
St. Gobain glass	73.9	13.6	12.6	.4
Same, old make	72	8.5	19	.5
Glass from two English factories	75.2	6.9	17	.9
	74.5	4.7	19.1	1.7
English glass, Ravenhead	75	6.5	18	.5
Amelung glass, from Dorpat	71	14.8	12.4	2.8

The mixture used in the leading glass-houses of Europe is: white sand, 300 parts; soda salt at 85° to 90°, 110 to 120; limestone, 50; glass fragments, 300. In some establishments the limestone is replaced by 45 parts of slacked lime.

The building or factory for the manufacture of plate-glass is generally of very large size. That of the British Plate-Glass Works at Ravenhead, where it is called the foundry, is 339 feet long by 155 feet wide; and the famous *halls* of St. Gobain in France is 174 by 120 feet. In the centre is the square melting-furnace, with openings on two parallel sides for working purposes, while along two sides of the great building are arranged annealing-ovens, which are sometimes 30 by 20 feet in order to receive the immense plates that are to be annealed. Two kinds of pots are used: the ordinary one, open at the top, for melting the glass; and cisterns or cuvettes, in which the molten glass is carried to the casting-table. In France the cuvette is usually of a quadrangular form, with a groove in each of its sides, or, as in the case of the larger cisterns, in two parallel sides, in which the tongs or iron frame are fitted when the cuvette is moved. Between each two pots in the furnace are placed, according to their size, one or more cuvettes. In some establishments the cuvette is not now used, the metal being poured from the pot in which it is melted on to the casting-table. In France 16 hours are allowed for the melting, and the same time for the metal to remain in the cuvettes; but the latter term is often extended in order that the aëriform bubbles may escape and the excess of soda become volatilized. Toward the last the temperature is allowed to fall, and the glass then acquires the slight degree of viscidity suitable for casting. The molten glass is transferred from the

pots into the adjacent cuvettes by means of wrought-iron ladles with long handles. When the glass is in the proper condition to be cast, the "tongs carriage," consisting of two powerful bars of iron united like two scissors-blades, and resting upon two wheels, is pushed into the opening made in the furnace, and the cuvette is clamped in the quadrant formed at the extremity of the tongs, two workmen manipulating the handles at the other extremity. The cistern, thus taken from the furnace full of molten glass, is placed on another carriage and quickly conveyed to the casting-table, Fig. 2176. This consists of a massive slab, usually of cast-iron, supported by a frame, and generally placed at the mouth of the annealing-oven. At the Thames Works in England the casting-plate is 20 feet long, 11 feet broad, and 7 inches thick. Formerly these tables were of bronze, and the great slab of St. Gobain of this alloy weighed 50,000 lbs.; but cast-iron was found less liable to crack, and is now generally used for this purpose. On each side of the tables are ribs or bars of metal, which keep the glass within proper limits, and by their height determine the thickness of the plate. A copper or bronze cylinder about a foot in diameter, resting upon these bars, extends across the table. After being heated by hot coals placed upon it, the table is carefully cleaned preparatory to casting. The cistern containing the melted glass is raised from the carriage on which it was brought from the furnace by means of a crane, its outside carefully cleaned, and the glass skimmed with a copper sabre. The cuvette is now swung round over the table, over which a roller covered with cloth is drawn to remove all impurities, and the molten glass poured out in front of the cylinder, which, being rolled from one extremity of the table to the other, spreads out the glass in a sheet of uniform breadth and thickness. The operation is a beautiful one from the brilliancy of the great surface of melted glass, and the variety of colors exhibited upon it after the passage of the roller. While the plate is still red-hot about 2 inches of its end is turned up like a flange, against which an iron rake-like instrument is placed, and the plate is thrust forward into the annealing-oven, the temperature of which is that of dull redness. Another plate is now immediately cast upon the hot table, and the annealing-oven when filled is closed and left for about five days to cool. The process of casting is done so systematically and with such dispatch in a well-regulated establishment, that the glass has been taken from the furnace, cast, and put into the annealing-oven in less than five minutes. From the annealing-oven the plates are taken to the warehouse, where they are carefully examined to see how they may be cut to the best advantage.

2176.

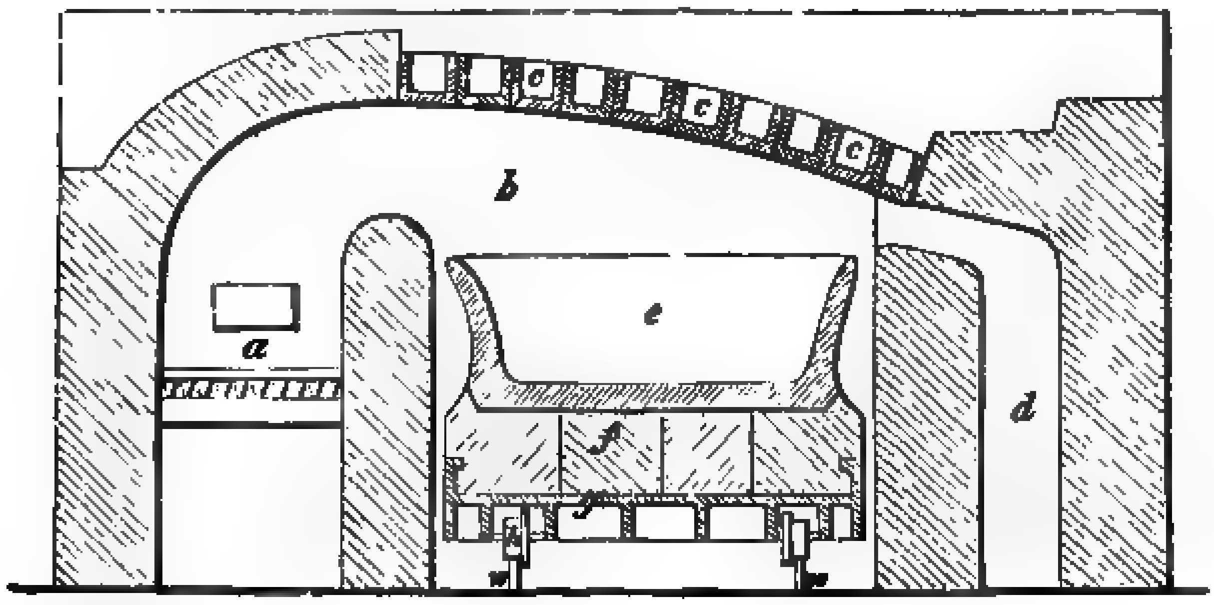
In different manufactories and at different times various processes have been in use for grinding and smoothing the surface of plate-glass, but the principle has been the same in all, viz.: rubbing the surface to be smoothed with another surface either of glass or iron, and at the same time applying sand or emery of different degrees of fineness and water between the two impinging surfaces. One of the most approved methods of grinding and smoothing the plates was introduced into England in 1856, and adopted in the British Plate-Glass Works. This apparatus consists of a revolving table, 20 feet in diameter, fixed upon a strong cast-iron spindle, and capable of running at an average speed of 25 revolutions a minute. Above the table frames are arranged to hold the plates of glass, which are laid in a bed of plaster of Paris, with the face to be polished resting upon the table. These frames also revolve on their centres by the friction of the table upon the glass, slowly, but so as to present each side of the plates they hold to an equal amount of rubbing as they are moved nearer to the centre of the table or farther from it. Sand and water are applied to facilitate grinding down the glass. The grinding by this process is found to be even and equal, and the machinery to work smoothly and steadily from the facility with which the plates accommodate themselves to the power applied. After grinding they are smoothed with emery powder of finer and finer qualities, and are thus prepared for polishing. By the process above described the grinding and smoothing are done by the same machine; but formerly two sets of apparatus were required for this purpose. By grinding, the surface of the plate is made true, but presents a rough appearance which is removed by the process of smoothing. At this stage it is somewhat opaque, but this defect disappears after the final process of polishing. This is performed chiefly by machinery. The plate of glass having been fixed upon the table by means of plaster of Paris, the surface is subjected to the action of a series of wooden blocks covered with felt and attached to a frame by which they are made to move over the surface of the glass. At the same time a polishing powder, generally red oxide of iron, is applied, while the friction may be increased by adding weight to the rubbers. Polishing sometimes brings out defects which were before concealed; the plates are consequently again assorted, and, if need be, reduced to smaller sizes. Bending the large plates or the smaller sheets of glass for the purpose of fitting them for bow windows, etc., is an especial branch of the manufacture. A core of refractory material and suitable shape is introduced upon the floor of the furnace; and upon this is laid the sheet to be bent, which as it softens by gravity conforms itself to the shape of the bed upon which it is laid.

The value of plate-glass varies greatly with the size. In the United States the price of a plate of standard British or French glass, 5 × 3 feet, is about $35; but when the dimensions are double, the plate being 10 × 6 feet, the price is increased to about $175. A plate 14 × 8 feet is valued at about $500.

In *Bessemer's method of casting plate-glass*, a reverberatory furnace is employed, Fig. 2177, with a low arch and descending flue *d*. The flame, proceeding from the grate *a*, plays upon the surface of the materials in the pot *e*, in the fire-space *b*. The arch is formed at that part which is most exposed

to the heat and the alkaline vapors from the mixture, of hollow bricks *c c c*, over which a draught of cold air is caused to play by connecting the space above the furnace with the ascending main chimney. The object of this cooling, which is of course attended with a loss of heat, is to prevent tears, consisting of the fusible product of the action of the alkaline vapors upon the ingredients of the bricks, from forming on the arch, and falling into the glass during fusion. The pot, *e*, is of very large dimensions, as large indeed at the lip on the one side as the width of the plates which it is proposed to cast with it. It is set upon a siege composed of large masses of fire-stone, and these are cemented together, as well as the pot upon them, by some bottle-glass, which, in the fused state, enters the crevices and binds the whole firmly together upon the strong-ribbed cast-iron frame *g*.

2177.



This frame moves upon four wheels *h* on a railway *w*, which extends beyond the furnace to the rolling machinery, to be described immediately. Thus pot, siege, and frame are all wheeled in and out of the furnace at once, as will be seen by reference to the section, Fig. 2178, where *i j* represent the hollow brick, or masses of stone, by the removal of which a free ingress and egress is allowed the whole carriage on the continuation of the rail. The pot and carriage fill the entire recess in the furnace, and the flame playing upon the top does not much affect the iron frame of the carriage through the bad conducting-stones which form the bed of the pot. Fig. 2179 is a longitudinal section through the middle of the framework and machinery, by means of which the pot and siege are raised, and the melted glass poured out between the rollers. It shows the pot in an elevated position and partly emptied

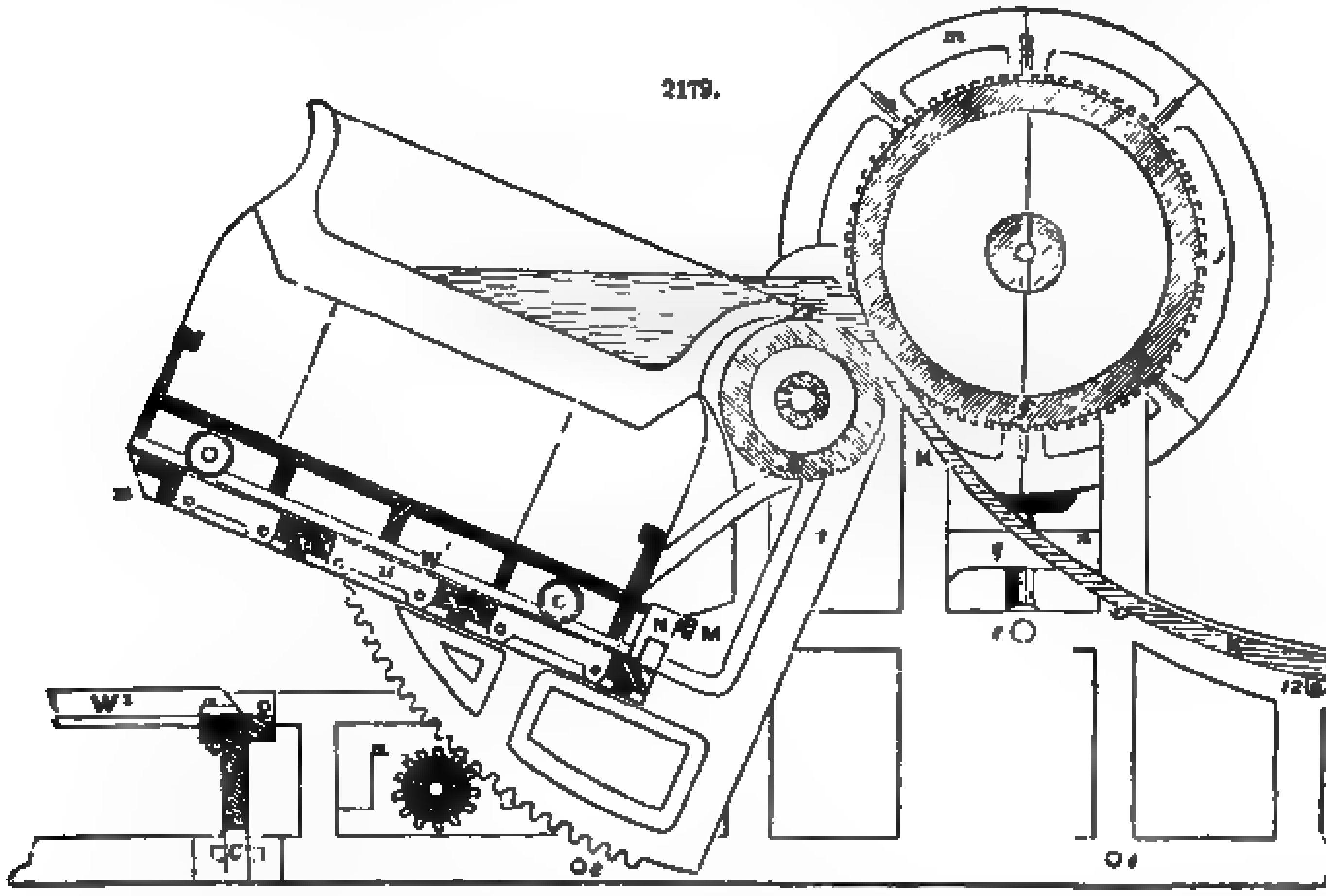
The mode of operating with this apparatus is as follows: When the glass is in a fit state for casting, the door is removed by a crane from the mouth of the furnace, and by the assistance of an iron hook the carriage and its pot are easily rolled forward upon the rails before mentioned to the tilting-frame *t*. The carriage and its pot are now moved forward until the set-screws *M* come in contact with the carriage; the office of these screws is to regulate the extent to which the lip of the pot shall overhang the roller *g*, so that when a new pot is used its proper position for pouring may be adjusted. The screws *M* pass through stout lugs *N*, cast on the piece *u*; the handle on *X* being turned, the pot will be elevated, as shown in Fig. 2179, when the glass passing between the rollers will be formed into sheets. When the pot is emptied it is again lowered and returned to the furnace for a repetition of the preceding operations. The roller *f* is furnished with a longitudinal rib, which at each revolution cuts the glass off into lengths.

2178.

Flint-Glass.—The best flint-glass is subject to defects, chief among which are undulatory appearances called *striæ*, resulting from a want of uniform density in the glass, and tending to refract and disperse in different directions the rays of light passing through it. These defects are of great importance when the glass is to be used for optical purposes. In 1758 John Dollond, an English optician, first began the construction of achromatic object-glasses, formed of two kinds of glass of different density; for this purpose he used fragments of flint- and of crown-glass, but did not succeed in making object-glasses with a larger aperture than 2 or 3 inches in diameter; and when the need of telescopes of greater magnifying power was strongly felt, it was difficult to produce flint-glass sufficiently free from striæ for a lens 4 inches in diameter. The invention of a means of producing flint-glass free from striæ was made by M. Guinand of Brennets, Switzerland, and it consisted

in working and stirring the material while in a state of fusion, by means of a tool made of the same material as the crucible or glass-pot. He made a hollow cylinder of fire-clay of the same height as the crucible, closed at its lower extremity and open above, with a flat ledge all round of several centimetres in width. Having heated this cylinder red-hot, he placed it in the melted glass; then, by means of a long bar of iron, bent to a right angle at a distance of some centimetres from its extremity, which he introduced into the cylinder of fire-clay, he worked and stirred the glass, by

2179.



giving the bar a horizontal rotary motion. For the manufacture of flint-glass, and of crown-glass, he adopted a circular furnace, in the centre of which is placed the crucible or glass-pot, all the parts of which are exposed to the same temperature; and covered crucibles are adopted, because with crucibles of this form there is no danger of the glass being spoiled by particles of the fuel, or by drops or tears from the crown or arch of the furnace. For the construction of this, see FURNACES, GLASS.

Flint-glass, of the usual density, similar to that used for table-sets, decanters, etc., is composed, ordinarily, of 300 parts of sand, 200 of deutoxide of lead, and 100 of subcarbonate of potash. The density of this flint-glass is from 3.1 to 3.2. The following composition, expressed in kilogrammes, gives the quantity necessary to fill the crucible: sand, 100 kilogrammes; deutoxide of lead, 100 kilogrammes; subcarbonate of potash, 30 kilogrammes. This composition gives a very white flint-glass, of a density of from 3.5 to 3.6, and which is perfectly suitable for opticians.

The details of the operation are as follows: The crucible is to be heated in a special furnace kept for the purpose, and when at a white heat it is to be introduced in the usual manner into the melting-furnace, which has been brought to the same temperature. This operation cools the furnace and the crucible. The furnace must be reheated in order to bring it to the highest possible temperature before introducing the materials. This takes about three hours. The throat of the crucible, which has been closed with two stoppers to prevent the entrance of smoke, is then opened, and about 10 kilogrammes introduced; one hour after, about 20 kilogrammes more; then, two hours after, 40 kilogrammes. Each time the crucible must be reclosed with the greatest care, and nothing must be put in until the coal on the grate ceases to give out any smoke. At the end of from 8 to 10 hours the whole of the composition will have been introduced. The crucible is left without being opened for about 4 hours; then the stoppers are removed for the purpose of introducing the cylinder of fire-clay, which has been heated separately to a white heat in the same furnace, and kept at that temperature until placed in the crucible; care is to be taken to keep it perfectly clean and free from ashes. At this period the flint-glass is melted, but it still contains bubbles. Nevertheless, the bent iron bar is introduced into the cylinder, and the first stirring is given, which serves to coat the cylinder with glass, and to effect a more intimate mixture. In about 3 minutes the iron bar is white-hot; it is taken out, and the ledge of the cylinder is placed on the edge of the crucible. This cylinder, being specifically lighter than the glass, floats slightly inclined, because its upper ledge is outside of the glass. The two stoppers are so replaced as not to push the ledge of the cylinder into the glass, and the stirring up of the fire is recommenced. Five hours afterward a fresh stirring up with a single iron bar takes place, the glass is already well refined, and then from hour to hour there is a stirring, each time with a single iron bar; great care being taken that at each stirring there shall be no smoke in the furnace, and that the lower doors of the furnace are closed. After having thus used 6 iron bars, from 25 to 30 centimetres in thickness of coal is thrown on the grate, which forms a mass quickly reduced to coke, and which allows the furnace to cool without exposing the grate

uncovered. The various openings of the furnace are unclosed; the whole furnace and the crucible thus gradually and slowly cool. This operation tends to cause the bubbles which are not yet disengaged to rise to the surface. At the end of two hours this operation is finished, and the furnace is again brought to the melting heat. After five hours of the highest temperature, the glass has resumed its greatest fluidity, the bubbles have disappeared, the grates are completely closed below, and the great stirring (*brassage*) commences; that is to say, as soon as one iron bar is hot, another is substituted for it, and so on for about two hours. At the end of this time the material has acquired a certain consistence, and the stirring is not executed without difficulty; then the last iron bar is taken out, and the cylinder is removed from the crucible, which is very carefully closed, as well as the chimneys and openings, except a small hole of two centimetres to permit the escape of the gas which may have remained in the fuel. When the disengagement of gas ceases, the furnace is entirely closed, and it is suffered to cool, which takes about 8 days. The door of the furnace is then removed, and the crucible with its contents taken out, usually in a single mass, except some fragments which become detached round it. The only object now is to make use of this mass and these fragments, the mode of doing which we will explain directly, after having given the details of the operation for crown-glass, which, as may be supposed, has a great analogy with the preceding.

Manufacture of Crown-Glass.—After many experiments, the following composition is found to be the best: white sand, 120 kilogrammes; subcarbonate of potash, 35 kilogrammes; subcarbonate of soda, 20 kilogrammes; chalk, 15 kilogrammes; arsenic, 1 kilogramme.

The crucible having been placed in the furnace, as for flint-glass, the introduction of all the materials is to be completed in about 8 hours, 4 or 5 hours after which the cylinder is to be introduced, and the first stirring takes place; then, every 2 hours, a stirring with a single iron bar; 6 are to be executed in this way. The furnace is to cool very slowly for 2 hours, after which it is to be reheated for 7 hours, this glass regaining its heat with much more difficulty than flint-glass. The great stirring then takes place, which lasts about an hour and a quarter. The crucible, the chimneys, and the openings are closed as for flint-glass, and the whole is left to cool. Parallel faces are made on the sides of the mass, whether of flint- or crown-glass, in order to examine the interior to determine the mode of division. It is then sawed into slices. Faces are also polished on the fragments for the purpose of examining them, and disks are made of them in accordance with their weight. For this purpose, they are first heated in a furnace and then introduced into a muffle, where only the heat necessary to mould them is given. If the fragment is irregular, it is partially rounded by the nippers and then moulded in a press, after which it is annealed.

Crystal.—This glass is sometimes termed flint-glass in England. It is chiefly notable as containing lead, the presence of which renders the glass more fusible and of higher refracting power, while giving to it a special sonority which renders it easily distinguishable. The following table shows the composition of various kinds of crystal glass, according to Peligot:

MANUFACTURE.	Silex.	Oxide of Lead.	Potash.	Soda.	Alumina.	Oxide of Iron.	Oxide of Manganese.	Lime.	Totals.
Vonèche crystal	61	33	6	...	..	..	..	...	100
Baccarat crystal	51.1	36.3	7.6	1.7	.5	.8	.5	...	100
Choisy-le-Roi crystal	54.2	34.6	9.2	.9	.5	..	..	.4	99.8
English crystal	57.5	32.5	9	1	..	..	..	...	100
English crystal (Faraday's analysis)	51.9	33.3	13.8	...	..	..	..	...	99
Moulded English crystal	61.3	22.3	7.1	7.5	.7	..	..	1	99.9

In large French establishments the usual composition of crystal is: sand, 300 parts; minium, 240 to 250; potash, 190 to 200. In England the following composition is used: sand, 300; minium, 150 to 180; potash, 220 to 270. For the manufacture of this glass into various objects, see GLASSWARE, MANUFACTURE OF.

Demi-Crystal.—This is a variety of glass largely used for vials, flasks, and cheap tableware. Peligot, among various compositions, gives the following: sand well washed, 300 parts; soda, purified and hydrated, from 55° to 60°, 130 parts; slacked lime, 50 parts.

Bohemian Glass.—This celebrated glass is almost as cheap as demi-crystal, while it is as brilliant and homogeneous as crystal itself. Peligot gives the following analyses of three samples:

NUMBER.	Silex.	Potash.	Lime.	Alumina and Oxide of Iron.	Totals.
1	77	14	8	1	100
2	76	16	7	1	100
3	75	13	9	3	100

The following is the composition used at the glass-works near Gratzen, Bohemia: pulverized quartz, 100 parts; slacked lime, 17; carbonate of potash, 32; oxide of manganese, 1; white arsenic, 3; together with from one-third to one-half the weight of the foregoing composition in glass scrap.

Slag-Glass.—The use of blast-furnace slag for the manufacture of glass has been proposed by Mr. Bashley Britten (see *Engineering*, xxii., 283). The slag is run directly into Siemens furnaces. Two of these furnaces are so provided that they can be relined or repaired alternately without stopping work. In working, these converting tanks are kept supplied with silica in excess; this may be in the usual form of sand, but flints, coarse sifted gravel, or fragments of quartz or any other silicious stone, are to be preferred when readily obtainable, as they form a more permeable mass, and are readily dissolved in contact with the basic slag. It is convenient that the fresh supplies of silica

should be introduced when no slag is running, in order that it may become heated in the interval to avoid chilling the slag when it is admitted; as the slag is introduced it is fed by a hopper or other means with the alkali. No stirring or mechanical agitation is needed, as the ingredients mingle of themselves; and, as they combine and become glass, this, being of a denser nature than the crude materials, sinks below them and forms a substratum of clear glass, with the yet imperfect glass and undissolved silica floating on its surface. The clear glass, as it is wanted, is tapped from the bottom of the tank, and received in a ladle holding a ton or more. This ladle is lifted by a crane, and is drawn along a tramway to the glass-house, situate as near as circumstances permit; when brought opposite to the opening at the back of the working-out furnaces, the ladle is tilted on its trunnions, and the glass is poured into the tank by a spout. The glass can then be used at once as it is, or its color or other quality may be changed by adding to it what is needed for that purpose.

The Bastie Toughened Glass.—By the process of tempering devised by M. de la Bastie, the hardness of glass is very much increased. The operation consists in immersing the hot glass in a bath of oils, grease, wax, or resinous substance, the temperature of which is above that of boiling water. Hardened glass will stand blows of about double the energy of those which will shatter ordinary glass of similar thickness. Its resistance to shearing stress is about three times that of common glass. On rupture, however, it disaggregates. It may be etched with hydrofluoric acid, or engraved with the sand-blast, without becoming impaired in point of strength. It cannot be cut with a diamond, as the removal of a portion determines the rupture of the entire piece. It is in use for photographic negatives, articles of table furniture, and lamp-chimneys, and has withstood the action of a cupel furnace at white heat for several days. The furnaces used by M. de la Bastie are described under FURNACES, GLASS. (See *Popular Science Monthly*, vii., 558. For tests of tempered glass, see *Scientific American*, xxxii., 402.)

Colored and Ornamented Glass.—Colored glass is produced either upon strass for imitations of precious stones, or by introducing the various oxides used for coloring into the materials of flint or other kinds of glass. In the latter case the coloring matter is thoroughly fused with the glass, which therefore becomes colored throughout its entire body. Pigments are also applied to the surface of glass, and sometimes by their greater fusibility are burnt or melted in. Flint-glass may be employed for vessels ornamented with colors, and to 6 cwt. of it the following ingredients are added for producing the respective colors: soft white enamel, 24 lbs. arsenic, 6 lbs. antimony; hard white enamel, 200 lbs. putty, prepared from tin and lead; blue transparent glass, 2 lbs. oxide of cobalt; azure-blue, about 6 lbs. oxide of copper; ruby-red, 4 oz. oxide of gold; amethyst or purple, 20 lbs. oxide of manganese; common orange, 12 lbs. iron ore and 4 lbs. manganese; emerald-green, 12 lbs. copper scales and 12 lbs. iron ore; gold topaz color, 8 lbs. oxide of uranium. The colors produced by the metallic oxides are found to vary with the degree of heat employed. All the colors of the spectrum may be obtained with oxide of iron; and these various effects do not seem to depend upon the different degrees of oxidation, but are thought to result from variations in molecular arrangement, induced perhaps by the action of light. By another process the surface alone of the glass may be colored. This is done by first gathering with the blowpipe a lump of clear glass, which after being rolled upon the marver is dipped into a pot of melted colored glass, forming a lump of colorless glass enveloped in a coating of colored glass. This is blown into a globe or cylinder and opened out into a sheet or plate in the usual manner, one surface of which is clear and the other colored. Vessels of various kinds having colored surfaces on the outside may be produced in a similar manner. By cutting through the thin layer of colored glass to the colorless layer, a great variety of colored ornamental glass may be produced. By gathering first a lump of colored glass and then coating this with melted clear glass, the external surface of the vessel will be colorless and the inner layer colored. "Casing" is a somewhat similar process. The article of flint-glass when partially blown is inserted into a thin shell of colored glass, prepared at the same time for its reception, and the blowing is continued till the inner one fills the shell, with which it is afterward well incorporated by softening in the furnace and further blowing. Several partial casings of different colors may be thus applied.

In making etched enameled glass, the enamel substance is ground to an impalpable powder, and laid with a brush in a pasty state upon the glass. After the paste is dried, the ornament is etched out by machinery or by hand, and the glass is then softened till the enamel is vitrified and incorporated with it. From this it is removed to the annealing-kiln. The flocked variety of enameled glass is prepared by the same method, except that a fine, smooth, opaque surface, like satin, much softer and smoother than that of ground glass, is previously given to the whole surface before the enamel is applied. This variety has in great part supplanted the other, and is justly much admired for the softening of the light diffused through it, and for the delicacy and beauty of the elaborate and artistic designs with which it is ornamented.

Works for Reference.—Among the most valuable treatises on the subject of glass are "Curiosities of Glass-Making," by Apsley Pellatt (London, 1849), and "Guide du Verrier," by G. Bontemps (Paris, 1868), both of these authors having been for many years extensively engaged in the manufacture of glass. Among other works are those of Neri, "The Art of Glass" (translated, London, 1662); Shaw, "The Chemistry of Porcelain, Glass, and Pottery" (London, 1837); Henry Chance, "On the Manufacture of Crown and Sheet Glass," London, 1856, and "On the Manufacture of Glass," 1868; Peligot, "L'Art de la Verrerie," Paris, 1862; Turgan, "Les grandes Usines de France," Paris, 1862-'70; Cochin, "La Manufacture des Glaces de Saint-Gobain de 1665 à 1865," Paris, 1865; Gaffield, "Action of Sunlight on Glass," reprinted from the "American Journal of Science and Arts," New Haven, 1867; Sauzay, "La Verrerie," Paris, 1868, and "Wonders of Glass-Making in all Ages," London and New York, 1870; and "Rapports du Jury International" of the Paris Universal Exposition of 1867, vol. cxi. (Paris, 1868). See also "Le Verre, son Histoire et sa Fabrication," Peligot, Paris, 1877.

GLASS, ORNAMENTATION OF. The Venetians and Bohemians have long been celebrated for their skill and ingenuity in the production of ornamented glass. Examples of their handiwork are given in Figs. 2180 and 2181, Fig. 2180 representing a Venetian bottle, and Fig. 2181 a Bohemian drinking-glass. Many ingenious effects produced are imitations of ancient manufacture, of which many wonderful specimens are preserved in European museums. The process of drawing out tubes is an interesting one. The workman, having gathered a lump of glass on the end of a blow-pipe, expands it into a globular form with very thick walls. Another workman having attached a punty to the opposite end, the two men separate from each other as quickly as possible, thus elongating the glass into a tube. The globe immediately contracts across the centre, which, being drawn out to the size of the tube desired, cools, so that the hotter and softer portions next yield in their dimensions, and so on until a tube of 100 feet or more hangs between the men. It is kept constantly rotating in the hands, and is straightened as it cools and sets by placing it on the ground. It is cut into suitable lengths while hot by taking hold of it with cold tongs. The diameter of the bore retains its proportion to the thickness of the glass; hence thin tubes must be drawn from globes blown to large size, or from small ones containing very little metal. In producing canes the glass is drawn out without being blown. Tubes thus drawn out from colored glass are converted into beads by other curious processes. This branch of the manufacture is extensively practised at Murano. The

2181.

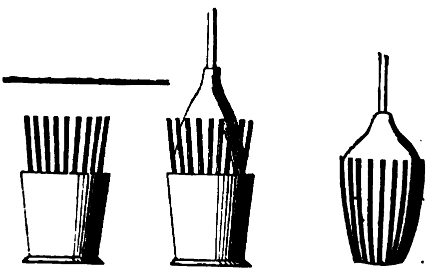
2180.

tubes are drawn out 150 feet in length, and to the diameter of a goose-quill, those for the smallest beads by the workmen receding from each other at a pretty rapid trot. The tubes are cut into lengths of about 27 inches and assorted for size and color. Women or boys then take several together in the left hand, and run them on the face of an anvil up to a certain measure, and with a blunt steel edge break off the ends all of the same length, which is commonly about twice the diameter of the tubes; the bits fall into a box. These are next worked about in a moistened mixture of wood-ashes and sand, with which the cylindrical pieces become filled; and they are then introduced with more sand into a hollow cylindrical vessel, which is placed in a furnace and made to revolve. The glass softens, but the paste within the bits prevents their sides from being compressed; they become spherical, and their edges are smoothed and polished by the friction. When taken from the fire and cleaned from the sand, they are ready to be put up for the market.

The Venetian *filigree glass*, which consists of spirally-twisted white and colored enamel glasses cased in transparent glass, is much used for the stems of wine-glasses, goblets, etc.; and when arranged side by side in alternate colors, it is manufactured into tazzas, vases, and other ornamental

articles. In making this kind of glass, pieces of plain, colored, or opaque white cane, of uniform length, are arranged on end, the different colors alternating, around the interior of a cylindrical mould (Fig. 2182). The selection and arrangement of colors depend upon the taste of the manufacturer. The mould and the pieces having been subjected to a moderate heat, a solid ball of transparent flint-glass, attached to the end of a blow-pipe or punty, is placed within the mould, the various canes forming an external coating to the glass, to which they become welded. The ball is now taken from the mould, reheated, and marvered till the adhering canes are rolled into one uniform mass. This being covered with a gathering of clear glass, the lumps thus formed, with the ornamental work in the interior, may be drawn into canes of any size, and presenting either the natural or the spiral arrangement, the latter being effected by the workmen rotating the glass in opposite directions while drawing it out into a cane. By variously arranging the colors in this process, and by skillful manipulations, many wonderful and ingenious effects are produced. Beautiful vases are also made by the above process, the glass when prepared being blown into that form instead of being drawn into canes. The *mille-fiori* consists of a variety of ends of variously-colored tubes, cut in the form of lozenges, which, having been arranged to represent flowers or other ornamental design, are enveloped and massed together with transparent glass. The lump is then worked into the required form, a very common one being hemispherical for use as paper weights. Portraits and even watches and barometers have been represented in the interior of glass; but in this case these articles and the glass have not formed a homogeneous mass, the former being arranged in a cavity of the latter.

2182.



Mosaic glass is produced by arranging vertically side by side threads or small canes of variously-colored opaque or transparent glass, of uniform lengths, so that the ends shall form a ground representing flowers, arabesques, or any mosaic design. This mass is now submitted to a heat sufficient to fuse the whole, all the sides at the same time being pressed together so as to exclude the air from the interstices of the threads. The result is a homogeneous solid cane or cylinder, which, being cut at right angles or laterally, yields a number of layers or copies of the same uniform design. This process was practised with great skill by the ancients, who are supposed to have produced pictures in this way; but in existing specimens, the pieces have been so accurately united, by intense heat or otherwise, that the junctures cannot even be discovered by a powerful magnifying glass.

Vitro di trino represents fine lace-work with intersecting lines of white enamel or transparent glass, forming a series of diamond-shaped sections, each containing an air-bubble of uniform size. In making this, a lump of glass is blown in a mould, around the inner sides of which are arranged pieces of canes of the required colors, as described in the case of filigree glass, which, adhering to the glass, form ribs or flutes on its external surface. The lump, having been twisted to give the spiral arrangement to the adhering canes, is formed into a conical shape and opened at the base. This forms the inner case of the *vitro di trino*. A corresponding outer case is formed in the same manner, which being turned inside out, the projecting canes appear on the inside of the cup with a reversed spiral arrangement. One case is now placed within the other, and both being reheated are collapsed together, forming uniform air-bubbles between each white enamel-crossed section. The two cases, thus welded into one, may be formed into the bowl of a wine-glass or other vessel.

Frosted glass, like the preceding, is one of the few specimens of Venetian work not made by the ancients; and although the process of making it is exceedingly simple, it was considered a lost art until recently practised at the Falcon Glass Works in England. The appearance of irregularly-veined, marble-like projecting dislocations, with intervening fissures, is produced by immersing the hot glass in cold water, quickly withdrawing it, reheating the ball of glass, and simultaneously expanding it by blowing.

Cameo incrustation is also of modern origin, having been first introduced by the Bohemians The figure intended for incrustation must be made of materials requiring a higher degree of heat for their fusion than the glass to be used. The figure, having been heated, is introduced into a cylindrical-shaped piece of glass, attached at one end to a blow-pipe and open at the other. The open end is then closed, leaving the figure in the interior of the hollow pocket. The air is now exhausted through the hollow tube, which produces a collapse and causes the glass and figure to form into a homogeneous mass. In making "paper weights," thin sections of little ornamented rods are placed in a circular iron mould or bed, in the form of the required design. A workman presses a piece of hot glass on the end of a punty into the mould and takes up the design. Then another workman drops a piece of hot glass on the opposite side of the design. The whole is now taken to the furnace, where the parts are welded into a hemispherical form, which magnifies the interior design and presents a fine picture inclosed within the transparent setting.

In making *spun glass*, the workman heats one end of a tube of glass, white or colored, by the flame of a lamp, and, seizing the softened end with a pair of pincers, draws out a long thread. Owing to the extreme ductility of glass, these threads can be drawn to an extraordinary fineness and length. In some cases spun glass has been made to imitate the hair of animals.

Crackle-glass (*verre craquelé*) is clear glass covered with an opaque layer of powdered or broken glass, producing a rough surface. This kind of glass is largely made in Bohemia. The broken glass is spread upon an iron plate, and the object to which it is to adhere is, while yet pasty, rolled upon the fragments. The ordinary blowing process follows.

Aventurine glass is a very beautiful imitation of the quartz of that name. It is yellowish in color, and through it are interspersed immense numbers of brilliant tetrahedric crystals of copper, protoxide of copper, or the silicate of that oxide. When polished, this glass is often set in precious metal for jewelry. The crystals are produced in the glass while it is yet liquid. As copper, iron, and tin exist among the numerous elements which compose glass, it is probable that this crystallization is attributable to the reduction of the copper oxide by the last-mentioned metals.

Chrome aventurine is made of sand, carbonate of soda, lime-spar, and bichromate of potash. It contains from 6 to 7 per cent. of oxide of chromium, about half of which is combined with the glass, giving it a beautiful greenish color, and the remainder exists dispersed throughout the material in the form of brilliant crystals. This glass is also used for jewelry.

Paste, or *strass*, which is used to imitate diamonds, and which constitutes all the cheap gems known under a multiplicity of sensational names intended to delude the ignorant, is a superior quality of lead-glass, of the following composition, according to Dumas: silex, 38.2; oxide of lead, 53; potash, 7.8; alumina, 1; borax and arsenic acid, traces; total, 100. These are about the same ingredients as enter into the fabrication of crystal. It is very soft, and is easily cut or scratched by other varieties of glass. Its distinguishing characteristic is remarkable brilliancy. To convert clear paste into imitations of gems other than the diamond, metallic oxides are added. Thus the *artificial topaz* consists of 1,000 parts white strass, 40 parts antimony glass, and 1 part purple of Cassius; *ruby*, the same, but heated longer and containing a little more gold; *emerald*, 1,000 parts white strass, 8 oxide of copper, and .2 part oxide of chromium; *sapphire*, 1,000 parts strass and 15 oxide of cobalt; *amethyst*, 1,000 parts strass, 8 oxide of manganese, 1 oxide of cobalt, and 2 purple of Cassius.

Glass pearls are largely manufactured in Venice, under the name of *rassades* or *rocailles*, in the same manner as already described for beads. Very beautiful imitation pearls called *baroques* are made in Paris, of exceedingly thin glass lined with gelatine and a nacreous matter obtained from fish-scales.

Glass Mosaics.—To make mosaic pictures in glass, small cubes of enamel are used. In the Vatican factories in Rome this material is produced in upward of 26,000 different shades. The work is begun by the designer, who traces on pasteboard in colors the design to be reproduced. The mosaic-setter then fills a shallow tray of lead, of the same size as the cartoon, with plaster, and draws the design in outline on the surface of the latter. The plaster is then gradually removed bit by bit, and the pieces of enamel which match the colors on the design are inserted in its place, the hollows being previously covered with moistened sand of a greasy nature produced from a volcanic earth found on Vesuvius. Where the cubes of enamel have to turn corners, they are ground to fit on a steel disk supplied with emery and water. When the cubes are all set in place, a sheet of paper or cloth is pasted over their surface, care being taken that all are caused to adhere. The lead tray is then reversed, the earth backing removed, and a mortar composed of Roman cement, lime, and pozzuolana is applied. When this sets, the enamel cubes are solidly fixed, and it only remains to wash off the paper or remove the cloth, and insert the mosaic in its frame or in the wall which it is to decorate.

Cutting and Engraving of Glass.—Four kinds of grinding-wheels are used in glass-cutting: 1, a wheel of wrought or soft cast-iron; 2, a wheel of sandstone; 3, a wooden wheel; and 4, a cork wheel. In France, where this operation is carried to the greatest degree of perfection, a so-called "company of cutters" includes three workmen, namely, the *ébaucheur*, *tailleur*, and *polisseur*, or designer, cutter, and polisher. The designer is usually the chief of the company. He prepares the design, and roughs it out on the object by means of the iron wheel, which is rotated either by a foot-treadle or by a motor. The wheel is mounted vertically, and is surmounted by a conical hopper filled with sand and water nearly in the state of mud. This falls upon the wheel, and is entrained by its rotation. The designer applies the object to the wheel, so that the friction of the sand grinds away the surface at the desired points. The object now passes to the cutter, who in his turn presents the piece to the sandstone wheel, which smooths away the asperities left by the sand. Finally the object goes to the polisher, who finishes its surface by application of the wooden wheel and pumice powder, and lastly of the cork wheel and colcothar.

The wheels employed by the cutters are quite large, often measuring 20 inches in diameter and over. Those used by engravers, on the contrary, are small, rarely exceeding an inch or two, and decreasing down to minute disks scarcely larger than the head of a pin. These wheels are of steel, copper, sandstone, and an alloy of lead and tin. Emery powder is used in a very fine state, and the lathe is operated by the foot of the workman. This mode of engraving has been largely supplanted, especially for coarse work, by the use of the sand-blast. (See Sand-Blast.)

Stained Glass.—Glass-painting, which is more properly a process of staining, differs from all other styles of pictorial art, except the painting of porcelain. The colors are different, being wholly of mineral composition, and are not merely laid on the outside, but fixed by being fused into the material, undergoing in the operation chemical changes that develop the brilliancy and transparency of which the compounds are susceptible. The colors are mixed with a flux of much easier fusion than the glass, and with some vehicle, as boiled oil or spirits of turpentine. The mixture is usually laid on with a brush as in ordinary painting; and the glass being then exposed to heat, the flux melts and sinks into the body. None of the clear bright colors are perceived until the work is completed, and the artist consequently labors under great disadvantage in applying the materials that are to produce them. He is guided either by lines drawn on the back side, which show through, or by a cartoon or drawing on paper placed there. In the early use of stained glass for windows, especially in churches, brilliant colors were highly esteemed, and great success was attained in the methods of coloring. A bright-red color was imparted by the ancients with the protoxide of copper. In later times it was found impracticable to succeed with this on account of the tendency of the copper to pass to a peroxide and produce a green tinge; but the practice has been again introduced with success by the Tyne Company in England, at Choisy in France, and in other places. The dis-

covery of the preparation of gold and tin, called purple of Cassius, also afforded another means of producing a brilliant red.

The process of producing a painted glass window is an interesting one. The artist first makes an outline on a small scale of the stonework of the window, within which he sketches the design, indicating the colors to be used and the general treatment of the subject. A full-sized drawing or cartoon is next made, from which a "cutting drawing" is traced, showing the lines where the strips of lead are to go, and omitting all other details. On this latter drawing, on which the colors of the design are indicated by outlines, the pieces of different-colored glass are laid and cut with a diamond, each piece being cut out of that particular color or tint required. The artist now arranges the pieces of different colors in their proper places on the cartoon, and traces the outline of the design upon them. On being heated in an oven, the opaque lines vitrify and are formed indelibly on the surface of the glass. After the outlines have been thus "burnt" on, the glass is taken again to the painter, who covers the cartoon with a sheet of colorless glass, or if large a portion of it at a time. Thus having the cartoon for a guide, he arranges in their proper places on the sheet of colorless glass the pieces on which the outlines have been traced, and secures them firmly with drops of melted resin and beeswax, or other suitable substance. The sheet of colorless glass, with the pieces thus arranged adhering to it, is placed upon an easel, and the shadows of the picture are put on with the same material as that used in tracing the outlines. The shading, however, is not traced from the cartoon, as were the outlines, but is done by the skill and experience of the painter. When the shading is completed, and the tints of yellow, if any are required, are put on, the pieces of glass are detached from the colorless sheet and again subjected to heat, for the purpose of "burning in" the shadows. If more work by the painter is required, the process is repeated, the glass being thus subjected to heat in some instances six or seven times. The work of the painter being completed, the finished pieces are taken by the "leader," who, having arranged them by the aid of the "cutting drawing" so as to form the entire design, fastens them together by means of strips of grooved lead skillfully fitted around the edges of the several pieces. If the window is a large one, as is generally the case, it is divided into parts of convenient size, which are fitted together when the window is put in its place. Bars of iron are also sometimes placed across the window at the line of junction and at other convenient intervals. This general process of producing mosaic stained-glass windows has been in use from the earliest times, though it may have been modified in some of its details; and until some other method of imparting colors to glass without detracting from its transparency and brilliancy is discovered, the opaque lead lines in the design must be accepted as a necessity.

Gilding on Glass.—This operation is performed by the same means as the similar operations on pottery; with the difference, however, that as vitreous products are much more fusible than ceramic materials, the proportions of vehicles to be added to the gold or to the coloring oxides are much greater.

A new process of gilding by M. Dodon is thus given by the *Moniteur de la Céramique:* Gold, chemically pure, is dissolved in aqua regia (1 part nitric and 3 parts hydrochloric acid). The solution effected, the excess of acids is evaporated on a water-bath till crystallization of the chloride of gold takes place; it is then taken off and diluted with distilled water of such quantity as to make a solution containing 1 gramme of gold to 200 cubic centimetres of liquid; a solution of caustic soda is then added until the liquid exhibits an alkaline reaction. The solution of gold is now ready for reduction. As a reducing agent an alcoholic solution of common illuminating gas is used, prepared by simply attaching a rubber tube to a gas-jet and passing the current of gas for about an hour through a quart of alcohol. This liquid (which should be kept in a closed vessel) is added in quantities of from 2 to 3 cubic centimetres to 200 cubic centimetres of the alkaline solution of gold before mentioned; the liquid soon begins to turn to a dark-green color, and at length produces the metallic layer of gold of known reflecting power. As an improvement on the process, as well as for convenience in executing it, there may be added to the alcoholic solution of gas an equal quantity of glycerine (28° to 30° B.) previously diluted with its own volume of distilled water. If the gold employed is an alloy, the foreign metals must in all cases be first removed; and especially the least traces of silver, because the very smallest quantity of this metal totally prevents the regular and uniform deposition of the gold.

Iridescent Glass, as manufactured under the patent of Mr. Thomas W. Webb, is produced as follows: Chloride of tin or tin salt is burned in a furnace, and the glass, having an affinity for it when hot, receives the fumes, and so at once an iridescent surface is produced. To give greater depth to the color or tints, nitrate of barium and strontium is used in small proportions. Very remarkable effects of iridescence also are produced in glass by long burial in the earth, as is evidenced by the collection of ancient Phœnician glass exhumed in the island of Cyprus by General Di Cesnola. Long exposure to ammoniacal vapors gives a somewhat similar result.

Electroplating of Glass.—Professor A. W. Wright has succeeded in depositing most beautiful films of gold, silver, platinum, and bismuth on thin glass by electro-metallurgical means. For a description of this process, see ELECTRO-METALLURGY.

Various applications of glass will be found under the following headings: For method of ruling glass to produce diffraction-gratings, see DIVIDING MACHINES; for its electrical uses, see ELECTRICAL MACHINES, STATIC. As to cutting glass panes, see DIAMOND.

GLASS-WARE, MANUFACTURE OF. The tools used by makers of glass-ware are few and simple, the various operations depending for success principally upon acquired dexterity, skill, and judgment. The implements are represented in Fig. 2183. The first in importance is the pipe or blowing tube, shown at 1, made of wrought-iron, 4 or 5 feet long, with a bore from a quarter of an inch to an inch in diameter, a little larger at the mouth end than at the other. It is a long hand, partly covered with wood, with which, the end being heated red-hot, the workman reaches into the pot of melted matter and gathers up the quantity he requires, and which afterward holds the article in the

manipulations to which he subjects it; and it is at the same time the air-tube through which the breath is forced to expand the vessel, or through which water is sometimes blown to produce the same effect by the steam it generates. A solid rod of iron, called a punty or pontil, serves to receive the article upon its end when freed from the pipe, adhesion being secured by the softness of the glass or by a little red-hot lump already attached to the punty. Spring tongs (5), like sugar-tongs, are used to take up bits of melted glass; and a heavier pair, called pucellas (2), furnished with broad but blunt blades, serve to give shape to the articles as the instrument in the right hand of the workman is pressed upon their surface, while, seated upon his bench, he causes with his left hand the rod holding the article to roll up and down the two long iron arms of his seat, upon which it is laid horizontally before him. At the same time the vessel is also shaped from the interior as well, and is occasionally applied to the opening of the furnace to soften it entirely, or only in some part to which greater distention is given by blowing. The pucellas are sometimes provided with blades of wood, as at 4. Another important instrument is a pair of shears (3), with which a skillful workman will cut off with one clip the top of a wine-glass, as he twirls it round with the rod to which it is attached held in the left hand. The edge, softened in the fire, is then smoothed and polished. Besides these, a wooden utensil called a battledore (6) is employed, with which the glass is flattened by beating when necessary; compasses and calipers and a measure stick are at hand for measuring; and a slender rod of iron forked at one end is used to take up the articles, and carry them when shaped to the annealing-oven, in which they are left for some time to be tempered. The marver (Fr. *marbre*, marble) is a smooth polished cast-iron slab, upon the surface of which the workman rolls the glass at the end of his tube in order to give it a perfectly circular form.

Wine-Glasses.—The manufacture of goblets, tumblers, and similar articles of table-ware may be illustrated by describing how a wine-glass in three parts is made. The workman, having gathered

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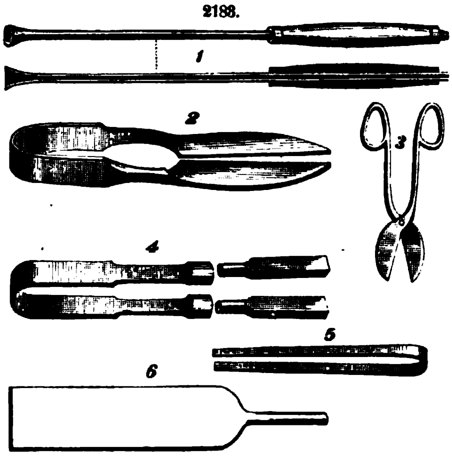

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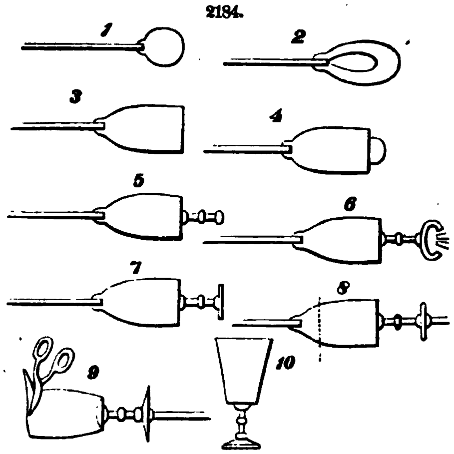

on the end of a blow-pipe the requisite amount of glass, as shown at 1, Fig. 2184, rolls it on the marver and expands it by blowing into the tube until it assumes the form shown at 2, and afterward, being flattened at the end with the battledore, that at 3. A lump of glass is now attached to the flat end of the bowl (4), which the workman with the pucellas, while rotating the pipe on the long arms of the chair in which he sits, transforms into the shape shown at 5. A globe is now attached to the end of this stem (6), which is afterward opened and flattened into the form represented at 7. A punty tipped with a small knob of hot glass is next stuck to the foot of the wine-glass, which is severed from the blow-pipe at the dotted line shown at 8. The top of the glass is then trimmed with shears (9), after which it is flashed and finished as at 10. It is now severed from the end of the punty by a sharp blow, and carried by a boy to the annealing-oven on the end of a forked rod.

Pressed Glass.—In the manufacture of articles by pressing, a hollow mould is used of steel or iron, with its interior surface so designed as to give the object the required shape and figuration. This mould may be in one piece or consist of several parts, which are opened when the moulded glass is taken out. The process will be illustrated by describing the production of a tumbler. A lump of glass is gathered from the pot on the end of a punty by the "gatherer," and being held over the open mould, a sufficient quantity is cut off with a pair of scissors by another workman and drops into the mould. This is now pushed under a hand-press, Fig. 2185, and a smooth iron plunger is brought down into the mould with such force that the hot glass is made to fill the entire space between the inside of the mould and the plunger, whose size and shape are the same as those of the interior of the tumbler. The plunger being raised up, the mould is taken from the press and turned over, when the tumbler is made to drop out bottom side up. A punty with a piece of hot glass at one end is now attached to the bottom of the tumbler, which is heated at another furnace and smoothed by being skillfully rubbed with a wooden tool while rotated on the arms of the workman's chair; after which it is taken on a fork to the annealing-oven. By this process articles can be produced with a rapidity not attainable in the case of blown glass, and therefore with less cost; but the latter is generally preferred.

The construction of a mould for large objects, such as decanters, is represented in Fig. 2186, and a section of it in Fig. 2187. The bottom *e* and the sides *a* of the body form the lower and larger part of the mould, and are held together by screws; the upper smaller part consists of two halves, meeting in the line *z z*, which open after the fashion of a pair of tongs when turned upon the hinge *d*. That they may not be extended more than is necessary, the two wings are impeded by the plugs *e* fixed to the ring *l*. The workman introduces the glass globe *g*, attached to the pipe, into the body

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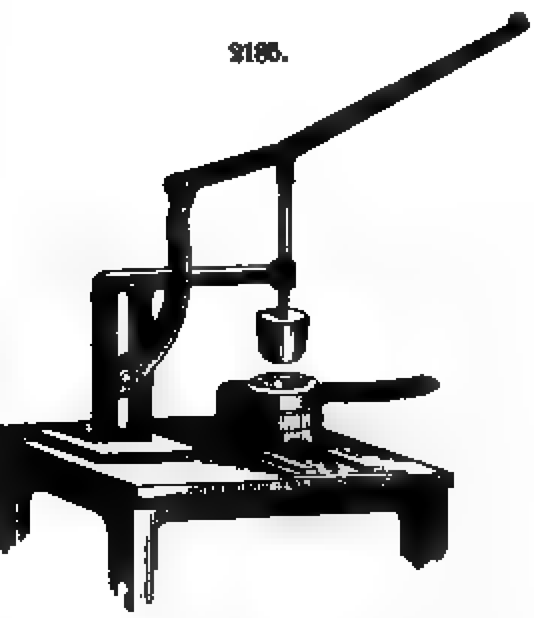


of the mould, the neck portion being thrown open, and blows with great force into the globe, as soon as the neck portion has been closed by an attendant, and fixed by the screw *m* (the female screw belonging to which projects at *n*). The glass is forced by the pressure against the sides of the mould, and extends in the form of a cap at *g*, above the margin, where the pipe is detached in the direction of *z z*. The cylinder *h*, and another similar one, more at the back, are intended for the insertion of wooden handles. Massive pieces, such as plates, are formed by pouring melted glass between two plates of metal composing the mould, and the excess of glass is squeezed out from the crevices by applying weights to the mould.

All articles of flint-glass, whether blown, moulded, or pressed, require annealing previous to cutting or grinding. As they are frequently constructed of very different thickness, two kilns, which can be heated to different temperatures, are requisite; the larger and thicker pieces require that the kiln should be much hotter than is necessary for thinner pieces. These kilns are long, low buildings, arched over on the top. The various articles are all placed on sheet-iron trays. These trays are put into the kiln through the opening in front, and are all connected together by hooks, by which means they can be moved by a chain, worked by windlass or similar machinery, to the farther end of the kiln, and are thus gradually withdrawn from the hottest part, and, having arrived at the farther extremity, are removed at a temperature little above that of the atmosphere.

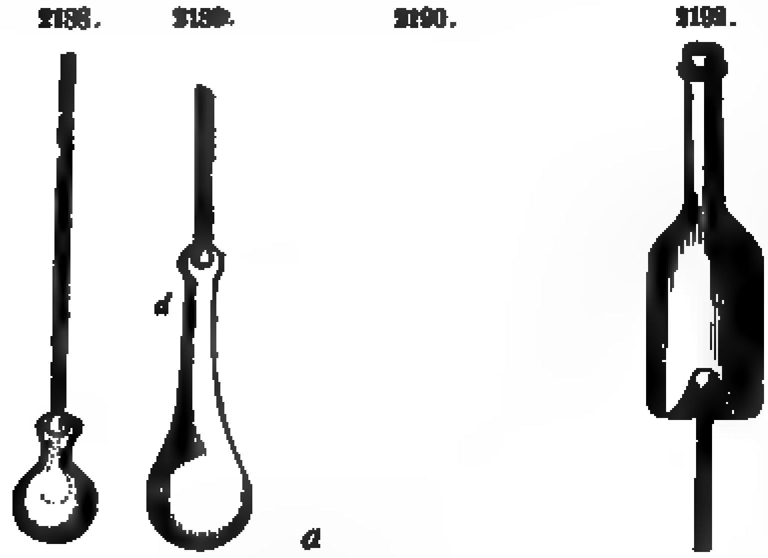
Moulded or pressed glass never exhibits its full amount of lustre, nor even the degree of sharpness of the metallic mould; the glass, which is never limpid in its liquid state, is first cooled by contact with the metallic surface, and is thus prevented from penetrating into the sharp corners of the mould, nor does it even accommodate itself perfectly to the flat sides. For this reason, the surface of moulded glass is not even, but always more or less curved, and the edges are not sharp; but the use of moulds as a preparatory step to grinding is of great advantage to the grinder, as the vessel acquires a perfectly regular form, and, although in a crude state, presents all the prominent and receding facets to be perfected at the lathe.

Bottles.—In choosing ingredients for this kind of glass, economy is the chief object. The following examples are calculated for 100 lbs. of sand: For champagne bottles, according to Jahkel—200 lbs. feldspar, 20 lbs. lime, 15 lbs. common salt, 125 lbs. iron slag; ordinary green bottle-glass—72 lbs. lime, 278–280 lbs. lixiviated wood-ashes; English bottle-glass—100 lbs. lixiviated ashes, 40–80 lbs. kelp, 30–40 lbs. wood-ashes, 80–100 lbs. clay, 100 lbs. cullet. As soon as the working-holes are opened, the workman attaches as much melted glass to the end of a blow-pipe as he considers necessary for the production of a single bottle. By dipping the previously warmed pipe into the pot, a little glass remains attached; after turning this in the air before the hole until it is cooled, and blowing slightly into it to render it hollow, a fresh layer of glass may be attached to it in the pot; to this a third is added in the same manner, until the ball at the end of the pipe has accumulated to a sufficient size. That this ball may become uniformly tractable in the subsequent forming, it is held by the workman in the flame of the furnace through the working-hole; it is then brought into one of the round concavities of the marver (constructed either from a stone, marble, or cast-iron plate), where the ball gradually assumes the form of a pear-shaped vessel, Fig. 2184. It acquires this shape by the constant rotary motion given by the workman to the pipe, while the cooling and stiffening of the mass is rendered uniform by the marver, and it is prevented from shrinking together by constantly blowing into the pipe with very little force. The mass of metal (metal is the technical term applied to glass during working) must be equably distributed round the axis of the pipe, and advanced in front of its mouth, being connected with it only by a short neck.

Thus far advanced, the glass has again become cool, and it is rewarmed by insertion into the work-

ing-hole, in such a manner that the front part receives the chief portion of the heat and becomes the softer. The pear-shaped vessel is now lengthened by the blower, and its form is approached to that of a bottle by a threefold operation: by blowing into the tube with greater force, by swinging backward and forward in the manner of a pendulum, and by a simultaneous constant rotary motion of the pipe round its axis. The globular form, which the glass tends to assume under the influence of the blowing, is converted into a long thin egg-shape by the swinging motion, Fig. 2189. The rotation round the axis of the pipe is an essential part of every operation in glass-blowing. The glowing mass of glass creates a powerful current of air in an upward direction, and the lower portion becomes cooled in consequence much more than the upper. This naturally creates an inequality in the resistance offered to the blowing, and the upper portion would be more expanded than the lower if the cooling influence were not allowed to act upon all parts of the surface alike by the revolving motion of the pipe; and this is particularly the case when the pipe has to be held in a horizontal position. The mould *a* (a simple cylindrical hollow block of wood or iron) is placed at the side of the workman who is blowing the pear-shaped vessel; into this he inserts the vessel as soon as it has acquired the proper thickness, in the manner represented at Fig. 2190, and by blowing forcibly into the tube, he presses the glass firmly against the sides of the mould, while, by a kind of jerking motion, the neck is drawn out to the proper length. The unfinished bottle is again warmed in the working-hole in such a manner that the lower part only is heated, while the other parts remain comparatively cool. In the mean time, another workman or a boy has attached a small quantity of glass to another pipe or rod of iron, called the *punty*, which is also kept hot in the working-hole. Both workmen now stand opposite to each other; and while the pipes are kept constantly turning, the punty is forcibly pressed against the middle of the lower part of the bottle, which is thus forced inward, and an even edge is produced, upon which the bottle may stand steadily. The bottle remains for some moments between the two instruments, Fig. 2191, until, by the application of cold iron or a drop of water, the neck can be separated from the pipe. This separation is an operation of constant recurrence in the glass-house, and is effected by a sudden change of temperature produced at the point of separation in the hardened glass, either by the cold application of a drop of water, or by the powerful heat of a red-hot iron or thread of liquid glass from the pot. The point of separation must often be reheated in order to fly on the application of cold water. The bottle is now supported by the punty, as shown at *a*, Fig. 2191, so that the neck can be warmed, and the sharp edges melted round without softening the other parts. A rotating motion is now given to the red-hot neck, the pipe being rolled backward and forward upon the knees of the workman. The rim for strengthening the neck is formed from a drop of glass taken from the pot by the edge of the flask and wrapped round the mouth in the form of a thick thread. The bottle, which is now finished, Fig. 2192, is immediately carried by the punty-rod to the annealing-oven by a boy, pushed into its proper place, and the punty-rod is lastly detached from the bottom of the bottle by a sudden sharp jerk. The place where the punty was attached is perceptible in every bottle blown in this manner by the sharp edges where the fracture occurred.

2188. 2189. 2190. 2192.



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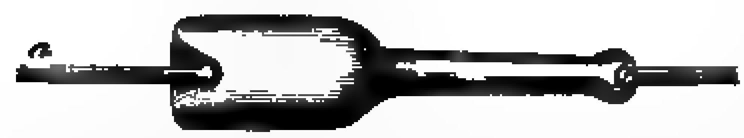


Large round bottles are blown without the use of a mould; and when of very large size, like the carboys for sulphuric acid, the aid of steam is called in, by spurting a mouthful of water into the interior, and holding the mouth of the pipe with the thumb.

Moulds are used of such construction as to secure the formation of a bottle, perfect both as regards form and capacity, at one single operation, without reliance upon the workman's correctness of sight. The use of moulds of this description, like that of Rickets, which is easily managed, affords a great saving of time, and renders the repeated heating of the bottles unnecessary.

The mould consists of a body which forms the belly of the bottle and of four other parts, a fixed bottom-piece with a movable piston for forming the concavity, and two movable pieces for the neck. Two treadles set these different parts in motion. As soon as the workman has introduced the hollow lengthened globe into the belly of the mould, by pressing with his foot upon the first treadle, he brings up the neck-piece, then forces the glass into contact with all parts of the mould by a powerful blast, and finishes the bottle by working the second treadle, which forces the pestle against the bottom. On the removal of the pipe, the rim of the neck is all that remains to be perfected.

Champagne bottles require to be made more than usually strong in consequence of the pressure exerted by the carbonic acid inclosed within them, and they are particularly liable to fracture during the bottle-fermentation of the wine. Yet they will often withstand a pressure of 40 atmospheres and upward (= 600 lbs. on the square inch).

The Manufacture of Mirrors.—Plate-glass has to undergo three operations before it is silvered. The first is smoothing. The rough plates are fastened with plaster upon a stone or cast-iron table. By means of a long beam of iron suspended from the ceiling and moved circularly, masses of wood

attached to said beam and faced with cast-iron are rubbed over the glass. On the surface of the latter coarse quartz sand is thrown and a constant fine stream of water is supplied. The coarse sand is subsequently replaced by a finer material, and this last by coarse emery. As soon as one side of the glass is finished, the plate is turned over and the other side similarly treated. Another method, largely used in France and England, consists in attaching the plates to a circular table of 15 or 18 feet diameter, which is rotated about a central pivot. Above the glass are placed heavy plates of wood faced with cast-iron. These plates, which are rotated by motion imparted from the table, but in an opposite direction, have counterweights, so that their pressure upon the glass may be adjusted; by means of this double movement the operation is greatly expedited. Sand and emery are interposed as already described.

The second process is rubbing with fine emery, made into a paste with water, in order to remove fine scratches. The glass rests on a table, and upon a wet cloth to prevent its sliding. Another plate of glass is deposited above it, and the two surfaces are thus rubbed together by suitable machinery.

The third process is polishing, and this is done by means of colcothar or red peroxide of iron, in a pure and fine state. The polishing apparatus is represented in Fig. 2198. The glass is fastened

2198.

to the movable tables *E*, which reciprocate in a direction relatively perpendicular to that of the brushes *H H'*, which reciprocate above and rub upon the glass. The brushes are moved by the geared mechanism shown. About 10 hours is required to polish about 50 superficial feet of glass.

The method of coating the plates is as follows: A large stone table, ground perfectly smooth, is so arranged as to be easily canted a little on one side by means of a screw set beneath it. Around the edges of the table is a groove, in which mercury may flow and drop from one corner into bowls. The table is first made perfectly horizontal, and then tin-foil is carefully laid over it, covering a greater space than the glass to be coated. A strip of glass is placed along each of three sides of the foil to prevent the mercury from flowing off. The metal is then poured from ladles upon the foil till it is nearly a quarter of an inch deep, and its tendency to flow is checked by its affinity for the tin-foil and the mechanical obstruction of the slips of glass. The plate of glass, cleaned with especial care, is dexterously slid on from the open side, and its advancing edge is kept in the mercury, so that no air or floating oxide of the metal or other impurities can get between the glass and the clean surface of the mercury. When exactly in its place, it is held till one edge of the table has been elevated 10° or 12° and the superfluous mercury has run off. Heavy weights are placed on the glass, and it is left for several hours. It is then turned over and placed upon a frame, the side covered with the amalgam, which adheres to it, being uppermost. In this position the amalgam becomes hard, and the plate can then be set on edge; but for several weeks it is necessary to guard against turning it over, as until the amalgam is thoroughly dried the coating is easily injured.

Several serious difficulties attend this process. The health of the workmen is so affected by the fumes of the mercury that they can rarely follow the business more than a few years; for this no remedy has been found so effectual as thorough ventilation and the frequent use of sulphur baths. The glass plates are liable to be broken by the weights placed upon them; and the coating of amalgam is frequently spoiled by the drops of mercury removing portions of it as they trickle down, or by its crystallizing, or by mechanical abrasion. Many methods of silvering have been contrived and patented with the view of obviating these defects, some of which are important. In 1855 a patent was granted in England to Tony Petitjean for a method of precipitating silver, gold, or platinum upon glass, so as to form a coating upon it, by the use of two solutions, the effect of which when mixed upon the glass is to decompose each other. The solutions he employed were different compounds of ammonio-nitrate of silver, tartaric acid, and distilled water; and they were placed upon the plate while this was at the temperature of 150° F. The precipitated silver within 20 minutes covered the glass, to which it adhered; and the solution being then turned off, all that remained to complete the mirror was to wash the surface, and when dry cover it with a coat of varnish to protect it from injury. The silvering thus obtained is not so white, and is rarely so free from blemishes, as

the amalgam coating. In 1849 Mr. Drayton made known a similar method, an improvement upon a process which he patented in 1843. He employed ammonia 1 oz., nitrate of silver 2 oz., water 3 oz., and alcohol 3 oz.; these, being carefully mixed, were all allowed to stand a few hours, when to each ounce of the liquid was added an ounce of saccharine matter, as of grape-sugar, dissolved in equal portions of spirit and water. Liebig invented a method of coating glass with silver, in which, after the silver coating is laid on, it is covered with a coating of copper precipitated upon it by the galvanic current, or is protected by varnish. Silver mirrors are now extensively made in New York. For platinizing glass, R. Böttger recommends the following process: Pour rosemary oil upon the dry chloride of platinum in a porcelain dish, and knead it well until all parts are moistened; then rub this up with five times its weight of lavender oil, and leave the liquid a short time to clarify. The objects to be platinized are to be thinly coated with the preparation, and afterward heated for a few minutes in a muffle or over a Bunsen burner. The brilliancy of aluminum has caused the suggestion of its application to the coating of mirrors; but no successful experiments have yet been made with it for this purpose.

Large mirrors are made in the United States by coating the imported plates. The old amalgamation method with tin-foil and mercury is preferred to any of the more recent inventions, by reason of the greater whiteness and brilliancy of the reflection and the greater permanence of the coating.

GLUE. All animal tissues contain an adhesive substance which anatomists call *histose*, in accordance with the name histology given to the study of the formation of these tissues. When they are boiled in water, the histose is changed into a new substance, called gelatine, dissolved in the water, from which it may be separated by simple evaporation, when it forms a dry, hard substance, which has different names corresponding with the various sources of its origin. That obtained from cartilage is called *chondrine;* from bones, hoofs, and hides, *glue;* from the air-bladder and intestines of fishes, *isinglass;* and from the less tenacious and adhesive constituents of parchment scraps and some other animal membranes, *size*.

The best kinds of ordinary glue are made from fresh bones, cleared of fat by previous boiling, and also offal obtained by trimming the skins for tanners. The pieces of dried skin thus obtained are called glue-pieces. The browner, commoner glue is made from offal from slaughter-houses, cattle-hoofs, etc. The skin-pieces are soaked in milk of lime for three weeks, the lime being renewed every week. They are then put in layers, on a sloping pavement, to drain and dry, and turned over three times a day. They are afterward soaked in weak lime-water, and washed in baskets under a stream of water. They are then drained and exposed to the air, so as to enable the adhering lime to absorb carbonic acid from the atmosphere, and thus lose its caustic properties, which would destroy part of the glue during the subsequent boiling. If the glue is to be used as gelatine for culinary purposes, only perfectly cleaned, fresh bones are used. Calf bones give a milky glue; those of the hog produce a blackish foam which mixes in the solution; while the product from those of the sheep retains always the peculiar odor of the fat of this animal. Beef-bones are preferred, giving a perfectly transparent glue, sold under the name of gelatine or isinglass. The materials (bones, skins, etc.) are placed in a flat copper boiler, upon a perforated false bottom, placed at a little distance over the bottom of the boiler, so as to prevent the solid material from touching the shell, when it would stick fast and be burned. The boiler is filled two-thirds with water, and heat is applied. In a few hours, after stirring repeatedly, the liquid is drawn off in successive portions, as soon as it is perceived that a sample taken out gelatinizes in cooling. Experience has taught that too long boiling injures the glue. The test for this cooled gelatinized material is, that it must be fit to be cut in slices with a wire. Before drawing off the solution the fire is diminished, so as to stop the boiling and allow the liquid to clarify by settling. It is then drawn into a deep boiler, where it settles for the second time, remaining hot from five to six hours.

The principal improvements in glue-making devised by Mr. Peter Cooper consist in the use of steam-heating of the vessels, and the application of heat under pressure, by which more glue is extracted in a much shorter period of time and with great saving of fuel; and the production of an opaque porous isinglass, made in winter only, when the frost, by expanding the water in the act of freezing, separates the glue particles. Being subsequently dried in the frozen state, they keep their spongy appearance, making them much more easily soluble, and thus better adapted for culinary purposes. Another improvement is the addition of Paris white (fine chalk) to the glue used by cabinet-makers. It has the following advantages: 1. It improves the adhesive qualities. 2. It makes the glue look more white, and thus gives to a browner glue the lighter appearance of a more expensive quality. 3. It is a pecuniary gain, since a substance costing only 3 or 4 cents per pound is added to one costing 30 or 40 cents.

Glue is also made from leather offal and old leather, by means of the action of 15 per cent. of hydrated lime and water in closed vessels, at a temperature of 250° F., and consequently two atmospheres pressure. In this way the leather is completely decomposed. Its principal constituents being tannic acid combined with gelatine, the lime takes hold of the tannic acid, forming tannate of lime, while the gelatine is set free and dissolves in the water.

The strongest glue is that which is purest and which gelatinizes most completely. Good glue, properly prepared and well applied, will unite pieces of wood with a degree of strength which leaves nothing to be desired. The fibres of the hardest and toughest wood will tear asunder before the glued surfaces will separate, and certainly anything more than this would be unnecessary. Mr. Bevan found that when two cylinders of dry ash, each an inch and a half in diameter, were glued together, and then torn asunder after a lapse of 24 hours, it required a force of 1,260 lbs. to separate them, and consequently the force of adhesion was equal to 715 lbs. per square inch. From a subsequent experiment on solid glue he found that its cohesion is equal to 4,000 lbs. per square inch.

The precautions necessary in applying glue are, to secure perfect contact of the parts, and to delay gelatinization of the glue until the joint has been completed. The glue should therefore be used

while very hot, as hot as it will bear, and in very cold weather the wood itself should be warmed. The glue should be well rubbed in with a stiff brush, and the two surfaces should be rubbed well together and retained in contact under great pressure until the glue has become somewhat dry. Complete dryness rarely takes place under several days; but after the lapse of 12 hours the joint becomes tolerably strong. A joint made in this way is probably as strong as can be made by any ordinary process.

Various modes of keeping glue in a liquid state are employed. The addition of a little nitric acid (10 oz. of strong acid to 2 lbs. of dry glue dissolved in water) will prevent the glue from gelatinizing or becoming solid; and the further addition of a little vinegar, or rather of pyroligneous acid, will prevent it from moulding. It has been proposed to add sulphate or chloride of zinc to common glue for the purpose of keeping it liquid. A solution of shellac in alcohol has been used and highly extolled as a substitute for common glue. It forms a tolerable liquid cement, but is far inferior to glue.

Marine glue, which possesses extraordinary adhesive properties, is a preparation of caoutchouc dissolved in naphtha or oil of turpentine, with the addition of shellac after the solution has by standing several days acquired the consistence of cream. Two or three parts by weight of shellac are used for one of the solution.

GOLD-BEATING. The art of preparing what is well known under the name of *gold leaf*, in which gold is hammered or beaten into plates, whose average thickness at the present day may be taken at $\frac{1}{250000}$ of an inch.

To manufacture gold leaf, the metal is required in theory to be in a state of purity. All alloy is at the expense of malleability. But in practice this is rarely if ever attained, and the usual fineness is that of coin, which in France and the United States is 90 per cent.; in Great Britain, $91\frac{2}{3}$ per cent.; and in Bavaria, where the principal amount of gold-beating in Germany is done, $97\frac{2}{10}$ per cent. fine. In France it was stated about 1820 that the most approved practice was to mix equal parts of old Spanish coin and pure gold, which would result in an average proportion of $95\frac{5}{8}$ per cent. fine. Below 75 per cent. fine, the manufacture would be, in labor and waste, a losing business.

The principal aim of alloying, when it is done of design, seems to be the production of a variety of color—silver making the leaf pale, copper deepening the tint. These effects are more particularly noticed in the article Alloys; they are similar in the leaf as in the more solid masses; only in the state of tenuity, the green and purple tinge is more easily excited and more vividly displayed. Whatever may be the character and degree of alloy, the manipulations of the gold-beater are the same in kind, and will be now briefly described.

1. *Casting.*—The metal is placed, with a little borax to promote fusion, in a black-lead crucible, or crucibles, and set in a furnace. When perfectly melted, it is poured into cast-iron moulds, 3 or 4 inches long, three-quarters of an inch wide, and about half an inch deep, and holding each about 1,000 grains of metal. These moulds are made with faces a little concave, to allow the cast to draw easily; and before pouring, they are heated, and rubbed with linseed oil or tallow on the inside, to drive off moisture and promote an easy separation. When sufficiently cool, the ingot is taken out, and reheated in an open fire, or a small annealing-furnace, by which it is softened, and the adhering grease driven off.

2. *Laminating.*—In older times this was effected entirely by the hand-hammer; now a flatting-mill or laminating rolls are employed. The French still use, however, a preliminary forging upon a steel anvil (of 3-inch by 4-inch sides), with a hammer of about 8 lbs. weight. The face of this hammer is about $1\frac{1}{2}$ inch square, and its handle about $6\frac{1}{2}$ inches. With this they bring down the thickness of the ingot to one-sixth or one-seventh of an inch. The English perform the whole of the operation in the rolls. As the success of the work and the excellence of the leaf ultimately depend a good deal upon the uniformity of the lamination, care is taken to use a proper and accurate machine. These machines have been successively improved, until now there is little if anything left to be desired. During the hardening processes of lamination and forging, if the latter be employed, the ribbon has to be frequently annealed, to prevent cracking. Formerly the lamination was thought sufficient which had brought the thickness down to one-twenty-fifth of an inch, with a width of one inch; and the balance was done by hand, cutting the ribbon into lengths of $1\frac{1}{2}$ inch, piling 24 of the lengths evenly together, and forging them all at once till they came square. This is the practice with some of the French and German gold-beaters to this day; but others, having access to more perfect machinery, continue its application to the lamination until the thickness is brought to about $\frac{1}{700}$ of an inch. As dimensions like this cease to be appreciable, the degree of lamination is estimated by weight; and the direction usually is, to bring it down until a square inch of ribbon weighs $6\frac{1}{4}$ grains. In this state it is ready for the *beating* proper.

3. *Beating.*—The implements and fixtures for this are, an anvil, hammers, skins, shears, parting-knives, etc. The *anvil* is a block of marble, weighing 250 or 300 lbs. or more, at pleasure, with a face of 9 inches to 1 foot square, carefully made even and smooth. This is set in a frame of wood-work, strong and solid, and upon a firm foundation. A ledge, 5 or 6 inches high, runs round three sides of the frame; to the remaining side an apron of leather is attached, which is lifted by the workman. The object of all this is to catch and retain fragments of the precious metal. The *hammers* are, ordinarily, four in number, varying in weight. Their faces are from 3 to 5 inches in diameter, and slightly convex. The weight of the first or flat hammer is about 15 lbs.; the second (which the French term the commencing hammer) weighs from 6 to 8 lbs.; the third, or spreading hammer, with a smaller face, and more convex, weighs about 5 lbs. only; and the last, or finishing hammer, is again a heavy one of 10 or 12 lbs., with quite a convex face. The skins are of parchment and vellum and the intestine already spoken of, cut, the two former into squares of about 4 inches, and the last of 5 inches. Besides these, there are packing-boxes, also of parchment, made on a form, and cemented together, open at two opposite ends, and in pairs, so that one will slip into the other, by which the open ends are closed. The knives are pieces of cane, set into a frame, both

four-square and cruciform, with sharpened edges that divide the attenuated leaf better than any other implement, by pressure downward only. When the leaf becomes very thin, any other motion would drag it.

Provided with these and other tools that do not require special mention, the workman lays off the ribbon, which comes from the laminating as nearly as possible one inch in width, into lengths also of one inch. This he does with dividers or a scale, and cuts off afterward with shears. This is on the supposition that the rolling has been uniform, and equal surfaces therefore should give equal weights. He then arranges these squares into piles of generally 150 pieces, laying each leaf on a piece of the vellum before spoken of, as near as may be in the centre, with their edges even. About twenty extra vellums are placed on top and at bottom, and the pack is then of proper size to be pushed smoothly into one of the parchment envelopes, which is then in its turn pushed into its mate, and the whole thus inclosed on all four sides. The pack is then laid on the marble anvil, and beaten until the small gold leaf is extended to the size of the vellum. It is in the judicious uniformity of direction and force of the blows that the skill of the workman is displayed. Great dexterity is, in fact, attained; the hammer is shifted from hand to hand for relief without interfering with the regularity of the stroke; and when it is recollected that the absolute effect of the average hammer with the average blow is equivalent to the steady pressure of about 2,800 lbs. on the square inch, there will be seen to be need for discretion in the application of such a force.

During the beating, the pack is frequently turned, so as to beat on the bottom as well as the top (as a skillful workman will do without losing the stroke), and also folded or rolled in the hand, to secure a proper detachment of the surfaces. It is also opened from time to time to watch the effect, and shift the leaves from the centre to the outsides, that the pressure may be uniform. When the gold has been extended to the size of the vellums, about sixteen times its original dimensions, it is taken out, cut up into four squares, repacked as before, only with gold-beaters' skin instead of vellum, and beaten over until similarly extended again. The caution of folding the pack to loosen the leaves is even more necessary now than before, and so of opening and shifting. When it has attained the size of the skins, it is removed, parted into squares again, but this time with the cane, repacked, and rebeaten as before into leaves of 3 to $3\frac{1}{4}$ inches square. It is estimated that the aggregate surface of the leaves is now 192 times larger than it was originally; and their thickness may be taken at $\frac{1}{146000}$ of an inch, which is about the average of English gold leaf, and corresponds to an extension of about 100 square feet to the ounce. But the operation is frequently carried further by repeated beatings, till an ounce is extended over 160 square feet, corresponding to a calculated thickness of $\frac{1}{234000}$ of an inch nearly. The French gold-beaters claim—and their statement of weight worked on and number of leaves produced warrants the claim—to carry it down ordinarily much further than this; and our statement at the beginning of $\frac{1}{250000}$ of an inch is probably even within the average result, and much within the possible limits, of malleability, if these were, without regard to expense of time and waste of metal, the only points to be reached.

The French workmen are also very precise in the number of pieces, both of leaf and of *baudruche* and vellum, which go to the packs in each of the five several steps that comprise their beating. As the fruit of experience, no doubt, they have ascertained the number which best suits the respective implements. The English and Germans pack in different numbers, it may be supposed with the same reason; but the principles of the operation are in all the same.

When the leaf is considered as finished, the last thing is to put it in the square books, such as we see in commerce. These are made of smooth paper, frequently reddish-colored, on purpose to heighten the lustre of the gold, and well rubbed with Armenian bole to prevent adhesion. There are two sizes, one about $4\frac{1}{4}$, the other $3\frac{3}{4}$ inches square: The pack, withdrawn from its parchment envelopes, is held by one of its angles; and, with a pair of wooden pliers, each leaf is withdrawn, and laid, aided by the breath, upon a leathern cushion, where, with the cane knives, it is parted at once or successively into four pieces, the size of the book. These pieces are then similarly transferred to the book, each between separate leaves. The book holds, very uniformly, 25 leaves of gold. When filled, it is pressed hard with a piece of wood of its own size, so as to bring its edges close; and with a piece of linen any projecting pieces of gold leaf are readily wiped off. Afterward the books are put up in packages of a dozen ordinarily, for sale. The French artists allow between 3 and 4 days for finishing 4 oz. of gold. They estimate the loss in trimmings, waste leaves, etc., at 50 per cent., and consider the remaining 2 oz. (964.6 grains English) as yielding 12,600 leaves of the smallest size; but there is no authentic experiment of weighings and measurings in this respect.

The *parchment* employed is used as it comes from the manufacturer, only cutting out of the sheets those parts, of suitable size, which are softest and of most uniform thickness. The *vellum*, which is produced of the finest and softest, is not further treated than by well washing it in cold water, drying it in the air under a press, and then powdering it with finely calcined and reduced selenite. Whether the implement used for this has any special influence will not be affirmed or denied; but the uniform practice, in France at least, is to use a *hare's foot*.

The preparation of *gold-beaters' skin*, from the colon of the ox, has been already spoken of as a secret maintained by the few who furnish the article. Whatever their processes may be, the gold-beater is accustomed to test and treat it still further for himself. Thus, he first *sweats* it, by placing it between a fold of foolscap; making a pile of many pieces, he treats it to a hearty hammering until it ceases to give out any grease to the paper. Next, he moistens it with an infusion of nutmeg, cinnamon, or other spicy aromatics, with the view of preserving it, dries it in the air, moistens again as often as he sees fit, and finally dries and presses it for use. Since the introduction of creosote, this (as well as may be judged from the odor of some recent skins) has been applied, and no doubt more effectually. After the skins have served some time (some 70 or 80 beatings, for instance), they become inspissated, or wiry, or both, and no longer allow the proper extension of the gold. This may be cured by laying them a half day between leaves of paper wetted with Rhenish or

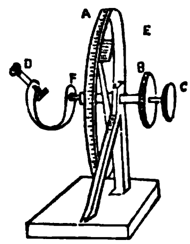
Moselle wine, or even vinegar and water. When thoroughly moistened, they are placed between layers of parchment, enveloped, and beaten until dry. This beating frequently takes a whole day. They are then powdered with selenite, and fit for use. While yet fresh, the skins are very liable to be affected by moisture, which they absorb from the atmosphere. They must be, therefore, always dried before using, which in France is done by heat in a screw-press. Care is taken not to desiccate too much, which withers and causes them to crack under the hammer.

The methods which have been described here are also applicable in their measure to silver, copper, and platinum.

A sort of gold leaf, called *party gold leaf*, is sometimes used, made with a combination of gold and silver. Separate leaves are taken of these metals, the silver being about three times as thick as the gold, heated and laminated together, so as to produce an alloy or welding of their surfaces. The resulting party-colored ribbon is then beaten as if it were all of gold. Its extensibility is, of course, not so great. There is another false gold leaf, which is better known as *Dutch gold leaf*. It is, in fact, a ribbon of brass, wash-gilded, sheared into leaves, and then beaten in the manner, and with more or less of the precautions, that have been described. When new, it is difficult to be distinguished from true gold leaf; but it is soon tarnished by the air, and is unfit for any gilding that is not to be varnished.

GONIOMETER. An instrument for measuring angles, and more particularly the angles formed by the faces of crystals. The instrument, chiefly used by mineralogists, was invented by Dr. Wollaston. It consists of a brass circle graduated on the edge, and furnished with a vernier, by which the divisions may be read correct to a minute. The circle moves in a vertical plane, and is supported on a stand. The axis of the circle is a hollow tube, within which is a smaller axis, fitting so tightly that when turned round it carries the other axis, and consequently the wheel, along with it, unless the latter is prevented from moving. The interior axis is furnished with a milled head *A*, Fig. 2194, and the exterior with a milled head *B*; so that when the head *A* is held and *B* turned, the circle may be moved independently of the smaller axis; and when *B* is held and *A* turned, the smaller axis may be turned independently of the circle. Attached to the end of the smaller axis is a sort of universal joint, capable of being fixed in different positions by means of screws. The crystal to be examined is attached to the joint at *C* by a little soft wax, and placed so that its edge shall be parallel to the axis of motion; which adjustment is obtained by placing it so that the image of some horizontal object, as the bar of a window, successively reflected from the two faces of the crystal, coincides with another horizontal line seen by direct vision. When this adjustment has been made, the instrument is turned till the horizontal object is seen reflected from one of the faces. The smaller axis is then held fast, and the other turned till the index of the vernier points to the zero of the graduated limb. The circle is then turned round, along with the smaller axis, till the same object is seen in the same position by reflection from the other face of the crystal; when the arc passed through by the circle is obviously the supplement of the angle formed by the two faces of the crystal. In order, however, to avoid calculation, the supplements of the angles are marked on the limb, so that the angle to be measured is read off immediately.

2194.



The name goniometer is also applied to a surveying instrument, somewhat similar to a theodolite.

GOUGE. See LATHE-TOOLS, TURNING.

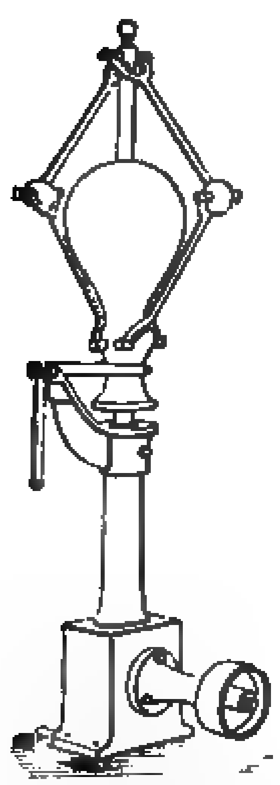
GOVERNORS. The ordinary steam-engine governor consists of two heavy balls suspended by links from a spindle, forming a combination known as the conical pendulum, and caused to revolve by some connection with the shaft of the engine. A conical pendulum, if there is no friction in the joints of the rods, stands in a position corresponding to the speed at which it is running. The height of the pendulum is the vertical distance of the vertex of the cone formed by the links, or the links produced, above the plane of the centres of the balls; and this height, which determines the position of the balls, is equal to the following expression, when there is no friction in the joints, or other resistance: $\frac{35{,}208}{(\text{revolutions per minute})^2}$. If, for example, the number of revolutions per minute is 100, the height is 35,208 ÷ 10,000, or about 3½ inches. The following table, calculated by Mr. Charles T. Porter, gives the speeds corresponding to various heights:

HEIGHT IN INCHES.	Revolutions per Minute.	HEIGHT IN INCHES.	Revolutions per Minute.	HEIGHT IN INCHES.	Revolutions per Minute.	HEIGHT IN INCHES.	Revolutions per Minute.
1	187.5	7.5	68.5	14	50.1	20.5	41.4
1.5	153.1	8	66.3	14.5	49.2	21	40.9
2	132.6	8.5	64.3	15	48.4	21.5	40.4
2.5	118.6	9	62.5	15.5	47.6	22	40
3	108.3	9.5	60.8	16	46.9	22.5	39.5
3.5	100.2	10	59.3	16.5	46.2	23	39.1
4	93.8	10.5	57.9	17	45.5	23.5	38.7
4.5	88.4	11	56.5	17.5	44.8	24	38.3
5	83.9	11.5	55.3	18	44.2	24.5	37.9
5.5	80	12	54.1	18.5	43.6	25	37.5
6	76.5	12.5	53	19	43	25.5	37.1
6.5	73.5	13	52	19.5	42.5	26	36.8
7	70.9	13.5	51	20	41.9	....	....

The actual height at which the balls revolve, in practice, is ordinarily much greater than that given in the preceding table—partly for the reason that there is some friction in the joints, but principally

because a weight or some other resistance is added, to increase the height. The advantage of this addition can readily be shown. The object of a steam-engine governor is to act on the throttle-valve or cut-off mechanism in such a manner, that when the load of the engine is increased more steam will be furnished, and when the load is diminished the supply of steam will also be cut off to a corresponding extent. By reference to the table, it will be seen that for a given change in the speed of the governor the change in the position of the balls is much greater as the height of the pendulum increases; so the effect of increasing this height is to render the governor more sensitive. There are various devices for increasing the height corresponding to a given speed; but the general principle upon which they act is essentially the same as in Porter's governor, Fig. 2195, which is probably in more extensive use than any other form. It will be seen that the balls of the governor are comparatively light, and that they are connected to a heavy central weight by levers of the same length as those connecting them to the spindle. If such a governor is revolving freely, the height will be to the height of an ordinary pendulum governor as 1 is to $\frac{2W+B}{B}$; in which expression W is the central weight, and B the weight of the two balls. Thus, if the weight of the balls is 100 lbs., and the central weight is 500 lbs., the height of this governor at any given speed is 11 times the height of an ordinary pendulum governor. Pickering's governor, Fig. 2196, acts on the same general

2196.



2197

principle as Porter's, but the position of the balls is controlled by springs of a peculiar form, instead of by weights. These two governors may be considered as representative of the best modern practice in regard to pendulum governors, although there are various modifications introduced by other makers, of more or less value.

The governors that have been described are position governors; that is, they regulate an engine by continually changing from one position to another, alternately increasing the speed of the engine and diminishing it, within a given range. In the case of governors similar to Porter's and Pickering's, the action is very similar to that of isochronous governors, which have the same height for all speeds, and so can remain without action on the controlling mechanism at one speed only. Isochronous pendulum governors are commonly made with rods having flexible ends hung to curved guides in the form of evolutes of a parabola, so that as the balls rise they describe parabolic arcs. The balls themselves are sometimes guided by parabolic arcs as they rise. The manner of designing such governors is explained in the *Scientific American* for Dec. 26, 1874.

The Huntoon governor, practically isochronous in its action, and representative of another class of governors, is represented in Figs. 2197 to 2199, and is thus described by a writer in the *Polytechnic Review* for Sept. 16, 1876:

"The corrugated cylinder A, Figs. 2198 and 2199, is filled to about two-thirds of its capacity with oil. On the inside, at the ends and on the periphery, are eight ribs, and between them intermediate ones on the periphery only. Inside of the cylinder is the paddle-wheel B, having six blades, and which, as shown in Fig. 2199, has but slight clearance in passing the ribs. The shaft or spindle of the paddle-wheel passes through a stuffing-box and a journal-bearing in the housing or frame, and carries the flanged pulley shown in Fig. 2197. Into the other head of the cylinder is screwed a stud which forms the journal for that end, and carries the pinion D, which gears into and gives motion to the segment E. Outside of the pinion is the scroll-wheel C, over which passes the flat-link chain, carrying the weights shown in Fig. 2197. The segment E vibrates the rock-shaft, to which is attached a short arm for lifting the valve, where the governor is of the throttle form. When the governor is to be applied directly to the cut-off, the long arms in Fig. 2197 are used.

"The action is as follows: The flanged pulley, being driven by belt from the main shaft of the engine, revolves the paddle-wheel B. As the oil in the cylinder offers a resistance to this motion, from being held by the ribs, the tendency is to carry the cylinder around with it. The weighted chain on the wheel C prevents this until the velocity of the paddle-wheel has reached such a point that the friction or resistance offered by the oil overcomes the inertia of the weight, when the cylinder also begins to revolve, and the pinion D, moving the segment E, closes the valve, and the speed is reduced, when the weights again bring the cylinder back to its original position. The operation is very quick, as may be demonstrated as follows: The paddle-wheel, making about 200 revolutions per minute, will not revolve the cylinder, as the friction of the oil is not sufficient to overcome the resistance of the weight; but an increase of a very few revolutions on the speed of the paddles will instantly move the cylinder *at nearly the same velocity*. Now, as the slightest motion of the cylinder is imparted to the valve, and as about two revolutions of the former will entirely close the latter, it is evident that the slightest increase of speed of the engine must cause the prompt closing of the valve.

2198.

2199

"The power which the governor is capable of developing may be thus demonstrated: Let P represent the power received from the resistance of the oil to the motion of the paddles; D the radius of the pinion, E of the segment; R the rock-shaft arm; W the resistance offered by the valve; C the radius of the cylinder. Then $P \times (C - D) \times (E - R) = W$. Take, for illustration, a cylinder 8 inches diameter, with a pinion (B) 1 inch diameter; radius of segment (E) 12 inches to pitch-line of teeth; rock-shaft arm for raising valve, 1 inch; power transmitted to cylinder, 15 lbs. Then $15 \times (4 - .5) \times (12 - 1) = 577.5$ lbs. actual power applied to valve."

When a governor regulates an engine by acting on the throttle, it is important that the valve should be properly designed. Many governors that were otherwise properly proportioned have failed on account of faulty valves. In designing a governor, the object to be fulfilled is that, with a given variation in speed, the two extreme positions of the governor shall correspond to a complete closure of the throttle and its opening to the fullest extent; and the governor should be sufficiently powerful to readily overcome all resistance to motion. While rules can be given for the approximate determination of these conditions, it is only by careful experiment that they can be exactly settled; and the best governors in the market are the result of practical tests by their manufacturers. Some examples of ordinary and novel forms of governors are appended.

Fig. 2200 is an example of the original form of the governor as introduced by Watt. The distinguishing peculiarity of this form consists in the connecting-links, $e\,e$, being situated *overhead*, and attached to the arms $a\,a$ by prolongations of the latter, which pass through a square part of the upright spindle A, to which they are both jointed by one pin. When at rest the balls are usually received into arms $g\,g$, curved to suit their surfaces, by which means the rods are relieved from all unnecessary strain.

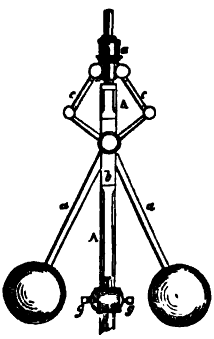
Fig. 2201 is a representation of a centrifugal governor, adapted to a small high-pressure *crank-overhead* engine. In this species of engine the governor is usually made to revolve in a short column B, cast in a piece with a forked bracket embracing the crank-shaft, and its spindle $A\,A$ is driven by a pair of bevel-wheels from the crank-shaft. The spindle is surmounted by a double brass socket b, attached to it by means of a pin; and to this socket are jointed the arms $a\,a$, which, as well as the connecting-links $e\,e$, are in this example finished in the lathe The sliding brass socket d, to which the lower ends of the links $e\,e$ are connected, is formed with a groove, into which is inserted the forked end of a lever D, having its centre of motion in a small wrought-iron column bolted to an arm projecting from the column B. From the opposite end of this lever depends the slender rod e, connecting it immediately with the throttle-valve lever, which by this simple construction is at once made to rise or fall, as the balls collapse or diverge in obedience to the varying speed of the engine.

Fig. 2202 is an example of an arrangement of the pendulum governor sometimes adopted in highly-finished engines. The peculiarity of this form consists in the connecting-rod e being attached directly to the sliding socket d, without the intervention of the forked lever. For this purpose the upper portion of the spindle $A\,A$ is bored out truly cylindrical, to a point somewhat below the range of the sliding socket d. This last is attached by means of a cotter to a small cylindrical hollow piece, which fits accurately into the interior of the spindle, and is consequently made to rise and fall with the socket d, a long slot being formed in the spindle to allow the cotter to traverse up and down. The lower end of the rod e is jointed to this interior piece by means of a swivel, so as to rise and fall with it, without being affected by its rotatory motion. At the top of the governor-spindle, the rod e is guided in its motion by being made to pass through the small brass vase which surmounts the whole apparatus; and should it be required to be of any considerable length, the necessary rigidity may be imparted by fixing a weight to it, as shown in the figure.

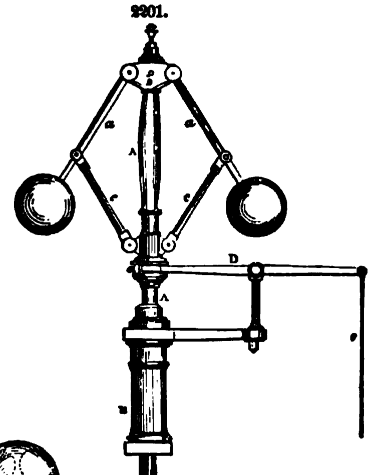
In the governor represented in Fig. 2203, the vertical spindle $A\,A$, which may be set in motion

either by a pulley or by bevel-wheels in the usual manner, is surmounted by two equal horizontal arms *a a*, furnished with stops at their extremities. The governor-balls run freely to and fro upon these arms by means of internal friction-rollers, and are drawn toward the common centre in the spindle *A*, by means of cords or steel ribbons *i i*, passing over two pulleys at *G*, and attached at their lower ends to the sliding collar *d*, in which works the forked end of the lever *D D*, which conveys the action of the governor to the throttle-valve. A spiral spring embracing the vertical spindle presses at its lower extremity against the sliding collar *d*, and its pressure is regulated by a sliding stop *h*, which can be fixed at any required elevation upon the spindle by a set-screw. The stop *h* having been set so as to cause the spring to press down the collar *d* with any approved force, and the throttle-valve opened to any required extent, the engine is set in motion. Should its speed exceed the stipulated rate, the increased centrifugal force will cause the two balls to diverge, and, raising the collar *d*, will partially close the throttle-valve and diminish the supply of steam, when, the motion being checked, the spring will press down the collar and cause the balls to collapse until the desired rate of motion is obtained. The degree of force exerted by the spring will always require to be adjusted to suit the nature of the work thrown upon the engine, because a small quantity of steam only will be required when the work is light, and a larger quantity when it is heavy,

2200.



2201.



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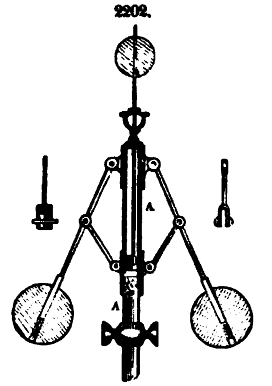

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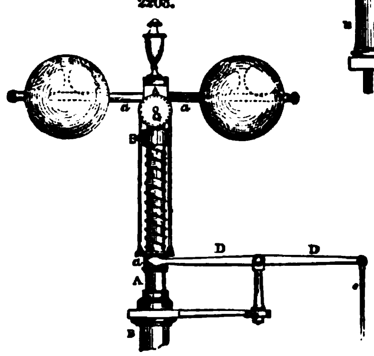

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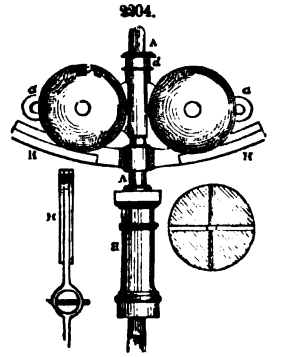


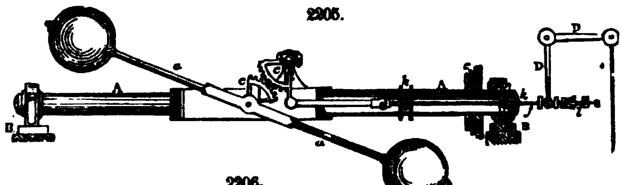
while the speed should in each case be the same; which conditions can be fulfilled with great facility and admirable precision by the use of this kind of governor.

Fig. 2204 represents a simple and compact modification of the centrifugal governor. Here the balls, instead of being suspended upon arms of a length proportioned to the velocity at which the engine is required to move, are fitted to traverse from and toward their common centre in the spindle *A*, upon the arms *H H*, which revolve with the latter, and are formed into circular arcs of a curvature determined by the same circumstances with the length of the suspending arms in the ordinary governor. By this means it is obvious that the horizontal plane of the rotation of the balls will vary with the varying speed of the engine, in precisely the same way as in the conical pendulum governor; and the vertical motion thus generated is transferred directly to the sliding socket *d*, which commands the throttle-valve lever. For this purpose, it is necessary that each of the balls should be made in halves and riveted together with a wrought-iron pin, as shown in the section, Fig. 2204; a space being left between the hemispheres to admit of the slotted arms *a a*, which are cast in a piece with the sliding socket *d*, and through which the connecting-pins are fitted to pass freely, but without allowing any play.

Another variety of the centrifugal governor is represented in Figs. 2205 and 2206; the former being a sectional elevation, and the latter a plan of a governor constructed by M. Bourdon of Paris, the peculiarity of which consists in the axis of rotation being horizontal instead of vertical. The main advantage proposed to be attained by this system is the more convenient transmission of the motion of the prime mover, whether by wheel-work or by pulleys. The principle of its action is the

same as that of the common governor. The spindle $A\ A$ is of cast-iron, the part to the left being hollow, while the middle portion is formed into a species of open framework, inclosing the principal part of the mechanism. It revolves in ordinary plumber-blocks $B\ B$, and is set in motion by the cone-pulley C. The arms $a\ a$, which carry the governor-balls, are supported upon a short axis working on the points of two steel pins, screwed into the central part of the spindle and secured by jam-nuts; this axis carries also a toothed sector c, working into a similar sector upon another short axis to which is fixed a lever d; the slender connecting-rods $j\ j$, traversing the hollow part of the spindle, and supported by the guides $k\ k$, serve to convey the motion of this lever to the throttle-valve gear, which is provided with suitable arrangements for adjusting the action of the governor upon the throttle-valve.

2205.



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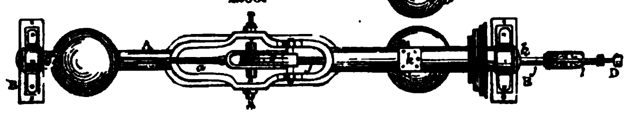
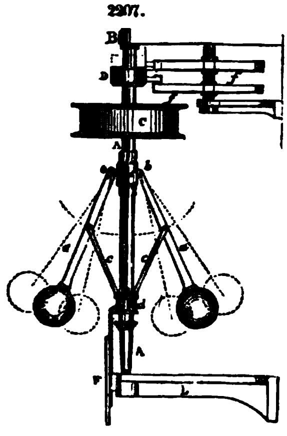


The object of the arrangement, Figs. 2207, 2208, and 2209, is to ring a bell, and to indicate upon a dial the velocity of rotation of millstones. This mechanism consists of a vertical wrought-iron axis $A\ A$, revolving in bearings $B\ B$, bolted to the wall of the mill, and carrying toward its upper extremity a pulley C which receives motion from the main driving-shaft. To this axis is fixed a brass socket b, to which are jointed the two flat arms $a\ a$, terminated by the governor-balls, and attached, about the middle of their length, by the two double links $c\ c$, to the sliding socket d, made in halves and connected together by two small bolts. To this latter are also attached the two slender vertical rods $e\ e$, which traverse the pulley C, and convey the action of the governor to a sliding disk D, provided with a projecting arm or catch, of such length as to come into contact, should the machinery exceed or fall short of its proper speed, with either of the two levers $f\ f$, which have their common centre of motion in a short vertical axis, and are attached at their opposite ends by slender wires to two sockets mounted upon a horizontal axis E; each of these sockets carries a bell, which, by the arrangement described, is rung when the catch on the disk D strikes either of the levers $f\ f$. To the sliding socket d is fixed a forked rod, having one of its branches formed into teeth like a rack: this rack gears into a small pinion, Fig. 2209, carrying upon its axis an index, which points out upon the graduated dial F the speed at which the millstones are revolving. Thus, should the velocity of the prime mover relax, the vertical axis A partaking of this diminished motion, the balls collapse, the socket d is pressed downward, and the rack causes the index to move from right to left. The opposite effect is produced by an increase of the speed (these different positions being indicated by the dotted lines in the figure). At the same time the bell is sounded by the apparatus which surmounts the governor; and the attendant, by a glance at the dial, is made aware of the change in the velocity of the machinery, for which he has to compensate by altering the degree of proximity of the upper and lower stones. It is well known that the action of the governor is in no way affected

2207.



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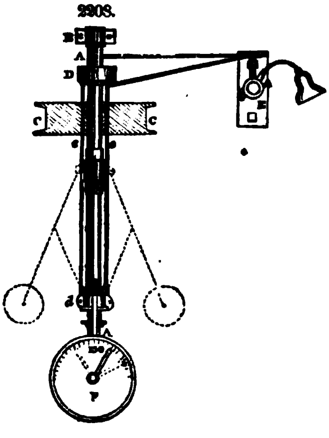
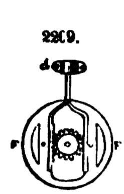


2209.



by the weight of the balls, further than that these should be made of a size proportionate to the resistance to be overcome; accordingly, in the case now before us, the work which the governor is destined to perform being very slight, the balls may be made of extreme lightness.

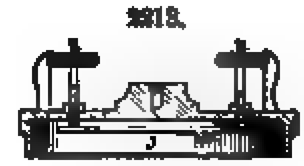
The air-reservoir or bellows governor is an apparatus of French origin, a patent having been granted to the inventor, M. Molinié of Saint-Pons, in 1838. The principle on which its action depends consists in causing the engine to force a quantity of atmospheric air into a reservoir with a movable cover through which the air escapes, the aperture being so regulated by an adjustable valve that it

shall only escape at a given rate. Should the speed of the engine exceed or fall short of the prescribed limit, the air is forced into the reservoir faster in the one case and slower in the other than it can escape through the valve; consequently the movable cover is raised or depressed, and, by means of suitable connections, partially closes or opens the throttle-valve. The advantages proposed by this system are: first, greater regularity and steadiness of action than is attainable by the common governor, combined with equal delicacy; and secondly, a more considerable range or amount of motion available for the purpose of regulation.

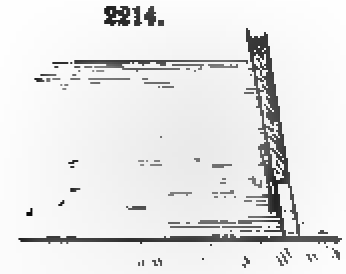
Fig. 2210 is an external elevation, Fig. 2211 a sectional elevation (on a plane at right angles to the former), and Figs. 2212 and 2213 sectional plans of this apparatus. The working parts are inclosed within a cylindrical vessel, the sole being formed of a cast-iron disk A, supported upon four small columns $a\,a$, and the cover of a cast-iron capital or cornice C; these are bound together by the four pilasters $B\,B$, having recesses formed on their edges for the reception of cylindrical sheet-iron panels, which thus admit of being removed at pleasure when it is necessary to examine or repair the internal parts. In Figs. 2210 and 2211 these panels are shown partially removed. Two small wrought-iron columns $D\,D$ are also fixed to the sole-plate, and serve to support a cylindrical cast-iron vessel E, the bottom plate of which is provided with two apertures guarded by the flap-valves d and g, which open alternately for the purpose of giving admission to the air which is forced into the receiver E by the double bellows $F\,F'$; these are respectively supplied with air from the

2210. 2211. 2212.

2213.



2214.



surrounding atmosphere by the apertures b and f, similarly furnished with flap-valves, the former being situated in the sole-plate A, and the latter in the movable piece G; the stream of air generated in the lower bellows passing through the upper by means of an elastic leather tube or copper pipe e. The cover of the fixed receiver E is formed of a movable cylindrical disk H, attached to the former by leather, in the manner of an ordinary bellows, and thereby admitting of being elevated or depressed, according to the degree of condensation of the air within the receiver; this is regulated by means of a small conical hole h, guarded by a pointed screw i, properly secured from turning, after being adjusted so that the air forced into the receiver when the engine is at its normal velocity shall just have liberty to escape, and consequently hold the movable cover suspended. Motion is communicated to this apparatus by means of two rods $l\,l$, fixed to the movable intermediate piece G, and attached by means of the connecting-rods $m\,m$ to cranks formed on the shaft I, which is set in motion by a belt from the prime mover working over the fast and loose pulleys $J\,J$. A round rod K, screwed into the movable cover H, serves to convey the motion generated by the governor to the throttle-valve or sluice-gearing, as the case may be. On this rod is fixed a ball L, which, for the sake of adapting the governor to the varying circumstances in which it may be placed, is usually made hollow and partially filled with lead.

Fig. 2214 is a representation of a mode employed by M. Molinié for rendering his governor most advantageously applicable to regulating the supply of water to a hydraulic motor. Besides the regular sluice-gate, he makes use of an additional valve N', to which, by means of the cord and pulleys shown in Fig. 2210, he attaches the governor. The face of this valve is bent into a cylindrical form, and it is jointed by rods to a central point considerably behind the sluice-face O'. By this means the strain arising from the pressure of the water against the back of the valve is counteracted, and the action of the governor rendered sufficiently delicate.

Fig. 2215 represents the connection of this governor with the throttle-valve of a steam-engine.

The efficient operation of this governor depends entirely on the perfection of the mechanism by

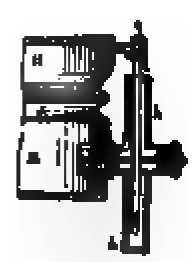
which the escape of the air from the receiver E is regulated. The simple contrivance detailed is altogether inadequate, as it is neither self-adjusting nor theoretically perfect in any circumstances, as will be obvious from the consideration that the volume of any fluid escaping by a given orifice depends not only on the section of that orifice, but also on the velocity of the escape; so that the higher the velocity, the aperture remaining the same, the greater will be the volume of issuing fluid. To compensate for this circumstance, M. Molinié devised an arrangement at once simple and effectual. Instead of the pointed screw i, he makes use of a conical pin i', Fig. 2219, which is attached by nuts to the movable cover H. It is fitted to move in the interior of a brass tube h', fixed to the stationary part of the air-receiver, and closed at the bottom, while the top is pierced with a hole of the exact size of the thick part of the pin. The air passes by an adjustable aperture into the interior of this tube; and according as the cover H is more or less elevated or depressed, the area of the aperture of escape is proportionally increased or diminished. By this ingenious contrivance, not only is the theoretical defect above alluded to corrected, but a great additional advantage is obtained in the more rapid and energetic action of the governor.

Figs. 2216, 2217, and 2218 represent two different modifications of the *vane governor*. The principle of its action consists in the atmospheric resistance to rapid motion being employed to counteract the force of gravity. The form represented in Fig. 2216 is that which illustrates the principle most clearly. On the crank-shaft is fixed a drum or pulley O, and underneath it, or in any convenient situation, is placed an axis carrying a small grooved pulley, to which are attached two or more fans or vanes $P P$. The former communicates motion to the latter by means of an endless band or belt, which is also passed over two friction-wheels, the first of which is attached to the weighted rod r, which commands the throttle-valve lever p, and the other to a gravitating weight q, suspended freely on the opposite side of the axis. The area of the vanes $P P$, and

2216.

2217. 2218.

2219.



the weight of the ball q, are so adjusted in relation to each other that the latter is just sufficient to drive round the resisting vanes at a certain velocity, exactly corresponding with the normal speed of the engine. Any increase of that speed, instead of accelerating the motion of the vanes (the atmospheric resistance being nearly uniform), tends to raise the weight and diminish the supply of steam passing through the steam-pipe N; and any relaxation of it allows the weight to descend, and thereby opens the throttle-valve in a corresponding proportion.

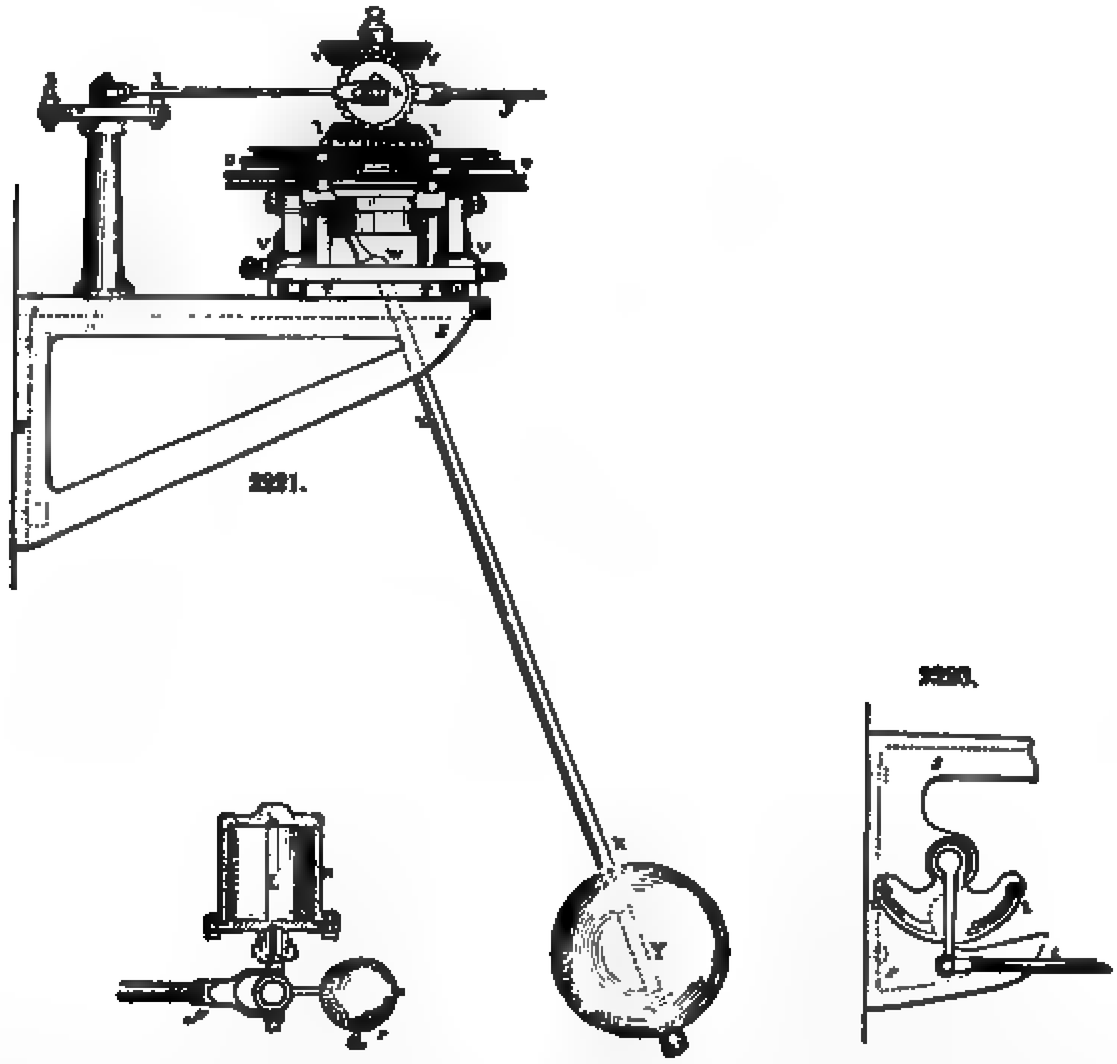
Figs. 2217 and 2218 are a side and end elevation of an arrangement in which this principle is carried out in a more practical and more generally applicable form. It consists of an upright spindle $s\,s$, supported in suitable bearings in a cast-iron standard R, placed, in the usual manner, over the crank-shaft Q of the engine, upon which is keyed a bevel-wheel, driving a pinion on the foot of the upright spindle, whereby a rapid rotatory motion is given to it. The upper part of the spindle is formed into a screw or worm, the threads of which slope at an angle of about 45°, and upon which a heavy bush or nut q is fitted to move easily. This bush, which is usually formed into a ball, and corresponds in its functions with the suspended weight q in the previous example, has attached to it two or more projecting arms furnished with vanes $P P$; these are so fitted upon the arms as to be capable of being set nearer to or farther from the spindle, as circumstances may require; they also admit of being turned upon the arms in an oblique direction, as shown by the dotted lines in Fig. 2218, in order to diminish the atmospheric resistance. The weighted nut is connected to the throttle-valve by means of a double link and swivel K, and by levers and rods $M M$, $n\,n$, in the usual manner. From the above description it will be seen that when the spindle s is driven in the direction tending to raise the nut q, the latter with its attached vanes will be carried round with it, and at the same velocity, until and so long as the resistance of the air against the vanes corresponds with the gravitating power of the weighted nut. But when the velocity of the engine, and consequently that of the spindle s, is increased beyond that point, the atmospheric resistance against the vanes will exceed the gravitating power of the nut and its mountings, and cause them to ascend upon the screwed spindle, and thus, by means of the connecting-rods and levers $K L M$, $n\,p$, will diminish the supply of steam passing through the steam-pipe N to the engine. If, on the other hand, the velocity of the spindle is reduced below that required by the resistance of the vanes to overcome the gravitating

tendency of the nut q, the latter will then descend upon the spindle, and thereby increase the passage for the supply of steam. The speed of the engine may be permanently varied at pleasure, by adjusting the vanes upon their supporting arms, so as to increase or diminish the gravitating power of the nut to the required extent.

The chronometric governor, Figs. 2220 to 2223, was invented by Mr. C. W. Siemens. The principle of its action appears to be an admirable and perfect one, involving as it does the happy idea of so combining the invariable motion of an *independent* pendulum with the varying speed of the engine or other motor, as to make the former correct *instantaneously* the fluctuations of the latter. Fig. 2220 is an elevation, and Fig. 2222 a section of this apparatus, which is set upon a bracket $S\,S$ bolted to the wall of the engine-house, and supported by a framework $T\,T$, consisting of four small columns and a circular entablature. The differential velocity between the engine and the revolving pendulum Y is obtained by means of the three bevel-wheels t, u, and v; this last is firmly connected, by an upright spindle and grooved arm w, with the upper extremity of the pendulum, produced through the ball-and-socket joint which forms its point of suspension and revolution. The under wheel t is fixed to the pulley U, which is driven by the engine with its uncertain velocity, and in the contrary direction to the motion of the wheel v. Both these wheels move in gear with the third bevel-wheel u, which runs perfectly free upon its axis, and is also permitted to travel round the perpendicular socket forming the bearing of the others. It is obvious that if t and v revolve in

2220. 2222.

2221. 2223.



contrary directions, but with equal velocities, the wheel u will also revolve on its axis, but will not change its angular position; while any difference in speed between t and v will cause the wheel u to follow the direction of the faster, which will at once alter the supply of steam, the arm x being attached to the throttle-valve contained within the steam-pipe N, by means of the lever and adjustable connecting-rod p and y. Another arm attached to the axis of the wheel u, on the opposite side of the perpendicular socket, is connected by means of the rod z to a lever working between two adjustable stops $Z\,Z$, which serve to confine the range of the throttle-valve within convenient limits. To maintain the motion of the pendulum a constant power is required, resembling that of the falling weight in an ordinary clock. This power is supplied by the weight r, which tends constantly to pull the wheel u to one side; and this strain, being borne equally by the wheels t and v, causes the latter, and with it the pendulum Y, to revolve, while the former, revolving in the contrary direction, is constantly engaged to raise the weight back again into its proper position. In practice it has been found that the power necessary for maintaining the action of the pendulum is much less than that required to effect the movement of the valve; and accordingly Mr. Siemens has adopted the principle of driving the pendulum with an excess of power, which shall be neutralized by friction apparatus when not wanted, and shall be allowed to act freely when the governor requires its assistance to move the valve. This is effected as follows: Surrounding the grooved arm w is situated a conical ring W, cast with the framing $T\,T$, and accurately bored out; against the interior of this "absorbing ring" a small piece of steel accurately fitted into the open end of the grooved arm w is pressed by the short end of the pendulum rod X, a spring being interposed for the purpose of letting the

pressure come on gradually. It is evident that whenever there is an excess of driving weight which causes divergence in the axis of rotation, the surface of the steel rubber and of the fixed ring will be pressed together with a force exactly sufficient to balance the excess; and so soon as the pendulum falls back toward a smaller arc of rotation, it will relieve the friction apparatus, and permit an increased supply of power to overcome the resistance of the valve. A second spiral spring is laid within the grooved arm *w*, behind the point of the pendulum, for the purpose of preventing the latter from dropping into its perpendicular position, and to facilitate its starting with the engine. The adjustment of the valve is effected at the very instant that the equilibrium between the power and load is disturbed; an advance of one-fiftieth of a revolution of the fly-wheel is found sufficient to close the valve entirely. By converting the friction apparatus into a regular brake, the power of the governor may be increased; and in this way it may be applied for the regulation of water-wheels, and such steam-engines as are furnished with variable expansion gear, which are better regulated by increasing or diminishing the amount of expansion than by throttling the steam.

Fig. 2224 represents Silver's marine governor. *A A'* are loaded arms pivoted in their centres at *B* to the shaft *C*, which receives motion in any suitable manner from the engine. The arms *A A'* are connected together through the medium of the sliding sleeves *D D*, the sleeve *D* being united to arms *A A'* by means of the rods *E E'*, and sleeve *D'* by means of the rods *E E*. *F F'* are brackets on the arms *A A'*, to which the ends of the rods *E E* are attached. These brackets are placed at an angle of 45°, so that the line of draught of the arms and rods, when the balls fly out, is always parallel to the shaft *C*. The centrifugal force of the balls is counteracted by the employment of a spiral spring *I*, to which the sleeve *D* is attached by means of clamps *G*. The tension of the spring is increased or diminished at pleasure by turning the nut *J*, which moves the claw-collar *K* out or in, thus rendering the governor accordingly more or less sensitive, as desired. The collar *K* terminates in a screw on which the nut *J* moves. When motion is communicated to the spindle by the engine, the balls will have a tendency to fly out in the direction of the arrows, and to move the sleeves *D D'* laterally. The sleeve *D* is furnished with a collar *H*, which is grasped by a forked crank *M*, pivoted to the standard *O*. The lower branch of the lever *N* is connected with a rod leading to the throttle-valve. The connection and operation of the sleeve *D'* on the throttle-valve are similar to those of ordinary governors, and require no particular description.

There are various other forms of marine governors, but the majority of them act on a principle somewhat similar to Silver's, Fig. 2224, or to Huntoon's, Fig. 2217. For accounts of several marine governors, and discussions of the subject, see "Transactions of the Society of Engineers," 1863; "Transactions of the Institution of Engineers in Scotland," v., xii.; and "Proceedings of the Institution of Mechanical Engineers," 1866. R. H. B.

GRAIN-DRILLS. See Agricultural Machinery.

GRAIN-MILLS. See Mills, Grain.

GRAPHITE (also termed plumbago and black lead, the latter an incorrect title, the substance not containing lead in any form). A mineral consisting of from 90 to 95 per cent. carbon, with traces of iron, silica, alumina, lime, and magnesia. It was formerly supposed to be the carburet of iron, from traces of iron found in many of the deposits; but iron and other impurities are only mechanical admixtures, no combination of graphite and iron or other substance having yet been found. It is found in nature in both a crystalline and an amorphous condition, opaque, of a metallic steel-gray color and lustre, a greasy unctuous feel when rubbed between the fingers, and giving a peculiar shiny

streak on paper. Its specific gravity is 2.09, rising somewhat above this as impurities increase. Its hardness ranges between 1 and 2. Crystallized graphite occurs in six-sided tables, belonging to the hexagonal system, cleaving perfectly in the direction of the base, and having the basal planes striated parallel to the alternate sides; but the mineral is more commonly found in foliated or granular form.

The black lead of commerce, and what is so called by the trade in first hands, is found principally in Bavaria and Austria. The plumbago of commerce comes mainly from the island of Ceylon, but is found in many parts of the United States, being mined successfully, however, only at Ticonderoga in the State of New York. It is also mined to a small extent in the Ottawa region of Canada.

Plumbago is very refractory. A piece with sharp projecting angles has been subjected for two hours to a heat that would melt steel, and on cooling the sharpest points were found perfect; but it will exhaust if left on top of such a fire. It is found in veins in a pure state, is removed in lumps, and a selection of these forms the "prime lump" of commerce. The formation most common in the pure state is that of laminated crystals, elongated at right angles with the sides of the vein, if not more than from 4 to 6 inches wide; but when the vein widens the crystallization often radiates from numerous centres, and the whole formation is very beautiful. The foliated variety is equally valuable and more brilliant, but rare in any quantity. The acicular form of crystal is not apt to be as pure in the lump, but is useful for most purposes. The granulated variety, the purest of all, is of little use for crucibles, but, with suitable manipulation, produces the finest grades for electrotyping and fine lead pencils. Pure plumbago is absolutely free from grit when pulverized and rubbed between the fingers; and the polish produced in the same way is instantaneous and very bright, being like a darker shade of polished silver. It is also found mixed with iron, rhomb spar and other forms of lime, the rock and earth in which the vein is carried, and many other foreign substances injurious for all the purposes for which pure plumbago is needed; so that much care is necessary in purchasing the raw material for a given purpose. Lime, for instance, is fatal to plumbago for crucible-making. The plumbago mined in the interior of the island of Ceylon is brought down to Colombo in bullock-carts. It is there selected into grades; so much as may be finely broken up is sifted, and the coarser part of this is called "chips," while the finer part is called "dust." The "dust" from prime lump is, of course, very different in character from the dust left from the poorer grades of lump; and all of it, whether lump or dust, after being handled and packed in barrels in Colombo, becomes so black and bright, by the poor particles rubbing against the good, that the touch of an expert is required to distinguish between the grades. The system adopted at Ticonderoga, by the Dixon Company, is to separate the mineral from its impurities by crushing and washing by the buddle process, and sizing the particles for different uses by floating in water.

The German black lead is not refractory, and is therefore useless for any purpose that brings it in contact with fire. It has no value for the crucible-maker or for stove-polish, and is of but little use as a lubricator. It has a very low conducting power even in its pure state, and the best quality that comes to market is far from pure. None of it comes in its original state as mined, but all of it is washed and floated, and so the grades are produced. In fact, it resembles a weak black clay more nearly than it does true plumbago, in nature as well as in appearance. It is used often on account of its cheapness, when it would be cheaper to use the real plumbago even at five times the price.

The most important applications of graphite are to the manufacture of lead pencils (see LEAD PENCILS) and crucibles (see CRUCIBLES). It is also made into stove-polish, for which purpose only the best quality of graphite should be used; and the finer it is pulverized the better, as each particle should be so small that it flattens out at once on the iron, adheres to it, and polishes quickly, while larger particles will fly off and be wasted, as well as creating a dust and requiring more labor to produce a fine polish. The polish from pure foliated plumbago will last on the iron for a long time, while that from German black lead will burn a reddish brown when the stove is raised to a red heat.

Graphite is also used for lubricating, and when so employed should be exceedingly fine and absolutely pure. For blowing-cylinders, the best quality of Ticonderoga, pulverized to the finest grade, pure and left with a good body, is the most economical. For engines, rolling-mills, and machine-bearings, the very finest should always be used. For wood bearings, after oiling with the plumbago a few times, the oil can be dispensed with, and the pure plumbago only applied in the dry powder. For metal bearings it should be freely mixed with oil. On hot axles or journals apply it freely dry, and then oil up as usual. (See LUBRICANTS.)

Graphite is employed in electrotyping (see ELECTRO-METALLURGY); as a facing for moulds; by piano-makers for coating the bridge over which the wires are drawn, to prevent the wires from adhering to the wood; by organ-builders to lubricate the slides; by hatters to impart a peculiar tone to the colors and a softness and smoothness to felt hats; by glass-makers for coloring dark glass for bottles, etc.; as a body for paint which is both water- and fire-proof; for coating the bottoms of boats; and for polishing gunpowder (see EXPLOSIVES) and shot. It is also combined in a refractory mixture for tuyeres, pointing up furnaces, etc. This is composed of equal parts of Dutch pipe-clay, fire-clay, half the quantity (by measure, not weight) of charcoal, and the same half quantity of silica (pure quartz sand, ground fine, being the best); to this mixture add as much of the plumbago as possible, and leave the mass thin enough to work. It should be made just thin enough with water, so that it will run rather sluggishly. O. C.

GRAVER. See LATHE-TOOLS, TURNING.

GRAVITATION, UNIVERSAL. See DYNAMICS.

GRAVITY, MEASURE OF. See DYNAMICS.

GRAVITY, SPECIFIC.* The ratio of the weight of one body to that of an equal volume of another, adopted as a standard of reference. For solids and liquids the standard is pure water, at a temperature of 60° F., the barometer being at 30 inches. Air is the standard for aëriform bodies,

* From the "American Cyclopædia."

A cubic foot of water weighing 1,000 oz., if the same bulk of another substance, as for instance cast-iron, is found to weigh 7,200 oz., its proportional weight or specific gravity is 7.2. It is convenient to know the figures representing this proportion for every substance in common use, that the weight of any given bulk may be readily determined; and for all substances the specific gravity is used among other tests for the purpose of distinguishing bodies from each other, the same substance being found, under the same circumstances, to retain its peculiar proportional weight or density. Hence tables of specific gravity are prepared for reference, and in every scientific description of substances the specific gravity is mentioned. In practical use, the weight of a cubic foot is obtained from the figures representing the density by moving the decimal point three figures to the right, which obviously from the example above gives the ounces, and these divided by 16 the pounds avoirdupois, in the cubic foot.

Different methods may be employed to ascertain the specific gravity of solids. That by measuring the bulk and weighing is rarely practicable, nor is it desirable. As a body immersed in water must displace its own bulk of the fluid, the specific gravity may be ascertained by introducing a body, after weighing it, into a suitable vessel exactly filled with water, and then weighing the fluid which is expelled. The proportional weight is then at once obtained. Wax will cause its own weight of water to overflow; its specific gravity is then 1. Platinum, according to the condition it is in, will cause only from $\frac{1}{21}$ to $\frac{1}{21.5}$ of its weight of water to escape, showing its specific gravity to be from 21 to 21.5. But a more exact method than this is commonly employed. The difference of weight of the same substance, weighed in air and when immersed in water, is exactly that of the water it displaces, and may consequently be taken as the weight of its own bulk of water. The specific gravity then is obtained by weighing the body first in air, and then, suspended by a fibre of silk or a hair, in water, and dividing the weight in air by the difference. If the body is lighter than water, it is to be attached to one heavier, to make it sink; then find the loss of the two by immersion, and also the loss of the heavier body; the difference will express the weight of water displaced by the lighter body, whose weight divided by this difference will give its specific gravity. It is hardly necessary to say that the substance examined must be free from mixture of foreign matters, and especially from cavities that may contain air. Minerals, if suspected to contain such, should be coarsely pulverized, and then the second method above may be conveniently applied to determine their density. The specific gravity of fine powders may be determined by one of the methods employed for ascertaining the specific gravity of fluids, viz.: by comparing the weight of a measured quantity with that of the same quantity of water. A glass vessel called a specific-gravity bottle is commonly employed, which is furnished with a slender neck, upon which is a mark indicating the height reached by 1,000 grains of water. The substance to be examined is introduced till it reaches the same mark, and, the weight of the empty bottle being known, only one weighing is required to obtain the result.

A common method for finding the specific gravity of fluids is by the instrument called a hydrometer or areometer, of which several kinds are in use, all dependent on the principle that the weights required to immerse a light body, as a bulb of glass, in different fluids, are proportional to the densities of these fluids. Such instruments are used for ascertaining the specific gravity of liquors, as an indication of their strength. (See HYDROMETER.) Gaseous bodies are weighed in a thin glass flask or other vessel made for the purpose, and provided with a stop-cock. The vessel is exhausted of air before the introduction of the gas. The experiment requires particular care, as the result will be found to vary under different conditions of pressure, temperature, and the hygrometric state of the atmosphere. The temperature of the air should be 60° and barometric pressure 30 inches. The specific gravities may also be calculated from the atomic weights of the gases: when the atomic volume is equal to that of hydrogen, it is obtained by multiplying the specific gravity of hydrogen by the atomic weight of the gas; when the atomic volume is half that of hydrogen, the specific gravity of the gas is equal to the specific gravity of hydrogen multiplied by twice the atomic weight of the gas; and when the atomic volume is twice that of hydrogen, the specific gravity of the gas is equal to the specific gravity of hydrogen multiplied by half the atomic weight of the gas.

The proportions of two ingredients in a compound, as in an alloy of gold and silver, may be found by multiplying the specific gravity of each ingredient by the difference between it and the specific gravity of the compound. As the sum of the products is to the respective products, so is the specific gravity of the body to the proportions of the ingredients; then as the specific gravity of the compound is to the weight of the compound, so are each of the proportions to the weight of its material.

The following table presents the specific gravities of substances most likely to be referred to, collected from various sources. The weight of a cubic foot in ounces avoirdupois is seen by moving the decimal point three figures to the right.

Table of Specific Gravities.

Acid, acetic	1.062
arsenic	8.591
boracic, crystallized	1.479
boracic, fused	1.803
citric	1.034
hydrochloric	1.200
nitric	1.271 to 1.583
aqua regia	1.234
phosphoric, liquid	1.558
phosphoric, solid	2.800
sulphuric	1.841
Alabaster	1.874
Alcohol, absolute	0.792
of commerce	0.835
Ale or beer	1.035
Alum	1.724
Aluminum	2.560 to 2.670
Amber	1.064 to 1.100
Ambergris	0.780 to 0.926
Amethyst, common	2.750
oriental, or violet sapphire,	3.309 to 4.160
Ammonia	0.875
Anthracite	1.360 to 1.850
Antimony	6.702
Asphaltum	0.905 to 1.650
Barytes	4.000
sulphate of (heavy spar),	4.300 to 4.720
Basalt	2.864
Beeswax	0.956 to 0.964
Bismuth	9.822
Brandy	0.837
Brass	7.824 to 8.396
Brass wire	8.544
Brick	1.900 to 2.000
Bronze, gun-metal	8.700
Butter	0.942
Cadmium	8.600
Caoutchouc	0.933
Chalk	2.784
Cinnabar	8.998
Clay	1.930
Coal, bituminous	1.020 to 1.350
Cobalt, cast	7.812
Copal	1.045
Copper, native	8.940
cast	8.788
wire	8.878
coin	8.915
Coral	2.540 to 2.850

Diamond	3.521 to 3.550
Dolomite	2.540 to 2.830
Earth, mean of the globe	5.210
Emerald	2.678 to 2.775
Ether, sulphuric	0.632 to 0.775
Fat of beef	0.923
Feldspar	2.400 to 2.620
Freestone	2.143
Garnet	3.150 to 4.300
Glass, bottle	2.733
crown	2.520
green	2.642
flint	2.760 to 3.329
plate	2.760
plate of St. Gobain	2.488
Gold, native	15.600 to 19.500
pure, cast	19.258
hammered	19.362
coin	17.647
22 carats fine	17.486
20 carats fine	15.709
Granite, Quincy	2.652
Staten Island	2.780
Graphite	1.987 to 2.400
Grindstone	2.143
Gunpowder, loose	0.836 to 0.900
close shaken	0.937 to 1.000
solid	1.550 to 1.800
Gum arabic	1.452
Gypsum, compact	1.872 to 2.288
Heliotrope or bloodstone	2.630 to 2.700
Hematite iron ore	4.500 to 5.300
Honey	1.456
Hyacinth	4.000 to 4.750
Ice	0.930
Iodine	4.948
Iridium, hammered	23.000
Iron, malleable	7.645 to 7.817
cast	7.207
ore, magnetic	4.900 to 5.200
Ivory	1.822 to 1.917
Lard	0.947
Lead, cast	11.350 to 11.445
white	7.235
ore, galena	7.250 to 7.750
Lime, quick	0.804
Limestone, compact	2.386 to 3.000
crystallized	2.722
Magnesia, carb	2.222 to 2.612
Malachite	3.700 to 4.000
Manganese ore (psilomelane)	3.700 to 4.330
Marble, Carrara	2.716
Parian	2.837
Egyptian	2.668
Mercury, common	13.568
pure	14.000
Mica	2.750 to 3.100
Milk	1.032
Myrrh	1.360
Naphtha	0.700 to 0.847
Nickel, cast	8.279
Nitre (saltpetre)	1.900
Oil, castor	0.970
linseed	0.940
olive	0.915
turpentine	0.870
whale	0.923
Opal	2.114
Opium	1.337
Palladium	11.300
Pearl, oriental	2.510 to 2.750
Peruvian bark	0.784
Pewter	7.471
Phosphorus	1.770
Platinum, native	17.000 to 18.000
refined	19.500
hammered	20.336
wire	21.041
laminated	22.069
Porcelain, China	2.385
Porcelain, Sèvres	2.145
Porphyry	2.458 to 2.972
Potassium	0.865
Proof spirit	0.923
Quartz	2.500 to 2.800
Rhodium	11.000
Rosin	1.100
Ruby	4.283
Salt, common	2.130
Sand	1.500 to 1.800
Sapphire, oriental	3.994
Serpentine	2.507 to 2.591
Silver, pure, cast	10.474
hammered	10.510
coin	10.584
Slate	2.110 to 2.672
Soapstone	2.650 to 2.800
Sodium	0.972
Spermaceti	0.943
Steel, hard	7.816 to 7.840
soft	7.838
Sugar	1.606
Sulphur, native	2.033
fused	1.990
Tallow	0.941
Tar	1.015
Tellurium	5.700 to 6.115
Tin, cast	7.291
hardened	7.299
Topaz	3.400 to 3.650
Tourmaline	2.940 to 3.300
Tungsten	17.400
Turquoise	2.600 to 2.830
Ultramarine	2.362
Vinegar	1.013 to 1.080
Water, distilled	1.000
sea	1.028
Dead Sea	1.240
Wine, Burgundy	0.991
white champagne	0.997
Zinc, cast	7.190

GRINDING. See Emery-grinding and Grindstones.

GRINDSTONES. Grindstones are used for giving a cutting edge to implements and tools, and also for removing by abrasion the surface of metal to prepare the same for painting or for polishing processes. The English, Nova Scotia, and Ohio grindstones are principally used; but each of these varieties is subdivided into different sizes and kinds of grit, the most prominent of which, and the work for which they are adapted, are as follows: *Newcastle*—Yellow color and sharp grit: the fine soft ones for grinding saws, and the coarser and harder ones for sad-irons and springs, for bead and face stones in nail works, and for castings (dry grinding). *Wickersly*—Grayish yellow color: for grinding saws, squares, bevels, and cutlers' work generally. A very soft grit to avoid taking out the temper. *Liverpool* (*or Melling*)—Of a red color and very sharp grit: for saws and edge-tools generally. An excellent grit for sharpening axes in ship-yards. *Nova Scotia*—Blue or yellowish gray color, and of all grits, from the finest and hardest to the coarsest and softest: the large ones for grinding sad-irons and hinges, springs, and edge-tools; the medium and small sizes for machine shops and for sharpening edge-tools generally. *Bay Chaleur, N. B.*—Of a uniform blue color, and soft, sharp grit: for table-cutlery, and admirably adapted for machinists' tools, and for sharpening edge-tools generally, when a fine edge is required. *Berea*—White color, fine and sharp grit: for sharpening edge-tools generally. *Amherst* (*Black River*)—Brownish-white color, soft, loose grit: for edge-tools, and the very soft ones for saws. *Independence*—Grayish-white color, and coarse sharp grit: for grinding springs and files, and for dry grinding of castings. *Massillon*—Yellowish white color, coarse, sharp grit: for edge-tools, springs, files, and nail-cutters' face-stones, and for dry grinding of castings. *Huron* (*Michigan*)—Of a uniform blue color, and fine, sharp grit: good for sharpening tools when a very fine edge is required. *Glass-Cutters' Grindstones*, of Newcastle, Warrington, Craigleith, and Yorkshire grits: for checkering, mitering, fluting, and for punty stones. *Curriers' Rubstones*, of Newcastle, Nova Scotia, and Ohio grits: for first and second stones; and Scotch Water of Ayr, Welsh, and Hindostan, for clearing-stones.

The grindstones used for removing surface metal are, when new, from 5 to 7 feet in diameter, and usually run at a speed of about 550 circumferential feet per minute. In order to maintain this speed, notwithstanding the reduction of diameter due to the wear of the stone, the pulley attached to the shaft upon which the grindstone is hung is replaced as the stone wears by a pulley of smaller diameter. Grindstones used to sharpen instruments usually run at a circumferential velocity varying from about 180 to 350 feet per minute. They should be kept very true by being turned up, which operation may be accomplished by using a piece of gas-pipe as a turning tool. For very particular work the grindstone requires to run so true as to necessitate the use of the black diamond or bort as a turning tool. The water applied to a grindstone softens it; hence the stone should not run in a trough of water, nor be allowed to stand with water applied to any part of it, for the reason that the softer parts wear away the quickest, and thus throw the stone out of true. The stone should be wetted from a pipe suspended above it, and provided with a cock to shut off the water when the stone is not in use.

A useful device for truing grindstones is shown in Fig. 2225. It consists of a hardened steel-threaded roll held in bearings in a frame or stand, which is bolted to the grindstone frame in such a position as to bring the thread upon the roll into contact with the face of the stone. The action is,

that the tops of the thread crush off the stone in minute sections or granular particles. The main stand or bottom piece is securely clamped upon the trough close to the face of the stone; then by turning the hand-wheel, the threaded roll is brought into contact with the face of the stone, and is allowed to remain so as long as is requisite to produce the desired result. The water is to be left as usual in the trough. When by long use the thread on the hardened roll becomes worn, it can be re-cut, which operation may be repeatedly performed.

In grinding tools and instruments, a cutting edge is formed by the line of junction of the two facets at the point of a wedge. The angle of these two facets one to the other is determined by considerations of strength, and the shape of each facet either by considerations of strength or of shape. As a rule, the harder the material to be cut, the more the approach of the two facets to a right angle, one with the other; and so likewise the greater the strength required, the nearer the facets to a right angle. Thus, while the facets of a graver may stand at an angle of 50°, those of the cutters for a pair of shears or a punching machine will stand at an angle of about 85°, though both may be used to cut iron and steel. In this latter case, the strength being the main consideration, it must be obtained at a sacrifice of keenness; whereas, if we take the case of a razor or a lance, sharpness is the main consideration, and strength is disregarded.

In determining upon which side of the stone any given tool should be ground, the workman takes into consideration the following points: the shape of the tool, the amount of metal requiring to be ground off, and the condition of the grindstone.

Upon the edge of a tool which last receives the action of the stone, there is always formed what is termed a feather-edge; that is to say, the metal at the edge does not separate from the body of the metal, but clings thereto in the form of a fine ragged web. If now we take a point on the circumference of the stone, as say at *F*, Fig. 2226, it should leave contact with the tool at the point of the tool denoted by *D*. Instead of doing this, however, the metal at the extreme edge gives way to the pressure, and does not grind off, but clings to the tool, leaving a web, as shown from *D* to *E*; whereas, if the same tool were held in the position shown at *G*, the point *F* upon the stone would meet the tool at the edge first, and would cut the metal clear away and not leave a feather-edge. Now the amount of the feather-edge will be greater as the facets forming the edge stand at a greater angle one to another, so that, were the facets at a right angle, instead of forming an acute wedge, as shown in Fig. 2226, the feather-edge would be very short indeed. But in all cases the feather-edge is greater upon soft than upon hard metal, and is also greater in proportion as the tool is pressed more firmly to the stone. Therefore the workman conforms the amount of the pressure to the requirements, by making it the greatest during the early grinding stage, when the object is to grind away the surplus metal, and the least during the latter part of the process, when finishing the cutting edge; and hence he obtains a sharper tool, because whatever feather-edge there may be breaks off as soon as the tool is placed under cutting duty, leaving a flat place along the edge.

2228.

The main principles involved in the art of tool-grinding may be practically applied as follows: First, to define the point which distinguishes whether the stone is running to or from you, let *A*, Fig. 2227, represent a grindstone, and *B*, *C*, *D*, *E*, and *F* tools held thereon. If a radial line from the centre of the stone forms an obtuse angle with the face of the tool which first meets a point on the periphery, or face of the stone as it is usually termed, then the stone is running from you; while if, on the other hand, that face forms an acute angle to the radial line, then the stone is running to you, no matter in what position in regard to the stone you may stand. In ordinary shop parlance, the side of the stone on which the face of the stone enters the trough is always called the side with the stone running to you, because all grinding which requires to be done with the stone running to you is performed on that side, and in conjunction with the use of the rest shown in Fig. 2227. It

is very dangerous to grind on that side of the stone without using the rest as a steadying point and as a safeguard. *B* and *C* are ground with the stone running from you, *D* is neutral, and *E* and *F* are ground with the stone running to you. Hence, with the stone running to you, the greater the angle of the front face of the tool (that is, the face which has the grindstone running toward it), the greater the liability of the tool to catch in the stone and the more difficult it is to hold the tool steadily, while the reverse is the case when the stone is running from you; and it follows that as the length of the cutting-tool edge is greater, the more difficult it will be to hold the tool in the position of *D*, *E*, or *F*. Therefore tools having broad cutting edges formed by acute angles should be ground in the position of *B*, unless, indeed, the stone is very true and smooth, and has no soft spots, in which case it is permissible to grind them held in a position relative to a radial line of the stone similar to that at *E*; but in this case it is well, while holding the tool at that angle, to grind it in that part of the circumference of the stone occupied by *D*, or between that and the position occupied by *E*, so that, should it chance to catch in the stone, it will not drag or force the fingers down to the rest.

2227

We may now consider what effect the size of the work has upon the position, relative to the stone, in which it should be ground, by giving a few examples of grinding. In the case of very small articles we may use almost any part of a true stone, because the hand has comparatively a thorough control of a small article. To grind the end face of any bar, the bar is always placed upon the rest, as shown in Fig. 2227 at *F*; but care should be taken to move the bar to various positions along the face of the stone, or slowly to revolve it, causing it to travel across that face, as otherwise a groove will be worn in the stone. Any work requiring to be ground to a point must be held in the position shown at *H*, Fig. 2226; it should be moved across the face of the stone as the grinding proceeds, to prevent the wearing of a groove in the stone. The surface of sheet-metal or plates should be ground in the position occupied by *D*, Fig. 2227. The cutting edges of all blades should be ground in the position shown at *G* or *H* in Fig. 2226, because they can be held steady, and, if held lightly toward the finish, with a small amount only of feather-edge. All drills should be ground upon the ends while upon the rest, excepting the faces of flat drills, as at *H*, while the diametral edges must be ground as at *F*, Fig. 2227. Anything that is sufficiently long to afford a *firm grip* with both hands when standing in the position of *F* may be ground in that position, providing that the top of the rest is close to the perimeter of the stone. All blades requiring a keen edge must be held lightly to the stone, to avoid getting broad and thick feather-edges.

After a tool is ground, it is often necessary to remove the feather-edge without having recourse to an oilstone. Machinists often accomplish this object by drawing the cutting edge across a piece of wood, holding the cutting edge parallel with the line of motion, which removes the feather-edge without breaking it off low down, as would be the case if the length of the cutting edge stood at a right angle to the line of motion.

Power required to drive Grindstones.—According to Hartig's experiments, to drive grindstones empty, the power is expressed by the following formulas:

Large grindstones empty, $P = .0000409\ d\ v$, or $P = .000128\ d^2\ n$.
Small fine grindstones empty, $P = 0.16 + .0000895\ d\ v$, or $P = 0.16 + 00028\ d^2\ n$.

In these formulas P = power required, d = diameter of stone in inches, v = velocity in feet per minute, and n = number of revolutions per minute.

The coefficients of friction between grindstones and metals are as follows:

	Coarse grindstones at high speeds.	Fine grindstones at low speeds.
For cast-iron	.22	.72
" wrought-iron	.44	1.00
" steel	.29	0.94

$$\text{Grindstone's net work: } P = \frac{P K v}{33{,}000}.$$

In this formula P = pressure between material and stone, v = circumferential velocity of stone in feet per minute, and K = the coefficient of friction. J. R. (in part.)

GUN. See AIR-GUN, FIRE-ARMS, and ORDNANCE.
GUN-CARRIAGE. See ORDNANCE.
GUN-COTTON. See EXPLOSIVES.
GUNPOWDER. See EXPLOSIVES.

GUTTA-PERCHA. A gum obtained from the *Isonandra gutta*, a tree indigenous to the Malay Archipelago. Its density is a little above that of water. At ordinary temperature it is supple, very tenacious, extensible, but not very elastic. At 112° F. it softens, and at 212° it becomes adhesive and pasty, so that it may be moulded into any desired form. On cooling it becomes hard and firm. It may thus be used for taking impressions of objects or for making moulds for electrotypers, as it preserves even the finest lines and markings. At 266° gutta-percha melts. At higher heats it boils and undergoes partial distillation, yielding a light solid residue and oils formed chiefly of isoprene and caoutchoucene. Normally of cellular texture, under strong traction it becomes fibrous and much more resistant. Thus, when by a powerful pull its length is doubled, it supports without breaking the strain of a force double that required to produce its extension. This resistance is not offered in all directions, as the material when thus extended is easily torn by transverse strain.

Gutta-percha is a bad conductor of heat, but the best insulating substance for electricity known. It welds easily, simple warming of the pieces being all that is required. It is insoluble in water at all temperatures, and withstands steam well. It resists the action of acids and alkalies better than India-rubber, and is unattacked by the most powerful of chemical reagents, hydrofluoric acid. It is soluble in alcohols and turpentine, and dissolves best in benzine, chloroform, and bisulphide of carbon. These agents do not cause it to swell as they do India-rubber, but gradually dissolve it from the surface to the interior. The solution becomes colorless on filtration, and if evaporated leaves gutta-percha in a pure state, when it resembles wax.

When exposed to air and light, pure gutta-percha becomes rapidly modified, disengaging a peculiar acid odor. The surface hardens and splits in all directions. Thus modified, the material loses most of its valuable qualities; it becomes even an electrical conductor, and is transformed into a kind of friable resin insoluble in benzine. Much of this resinous substance is found in commercial gutta-percha, owing to the exposure of the material. The alteration is best prevented by immersion of the substance in water in a dark place.

The following are some of the principal characteristics in which gutta-percha and India-rubber differ:

Gutta-percha, when immersed in boiling water, contracts in bulk, while India-rubber expands and increases in bulk.

Gutta-percha juice is of a dark-brown color, and consolidates in a few minutes after exuding from the tree, when it becomes about as hard as wood. India-rubber sap is perfectly white, and of about the consistence of thick cream; when it coagulates it gives from 4 to 6 parts of water out of 10; it may be kept like milk, and is frequently drunk by the natives.

Gutta-percha, first treated with water alcohol, and ether, and then dissolved in spirits of turpentine and precipitated, yields a substance consistent with the common properties of gutta-percha. Similar treatment of India-rubber results in a substance resembling in appearance gum arabic.

Gutta-percha by distillation yields 57¾ per cent. of volatile matter, while India-rubber yields 85½ per cent.

Gutta-percha in its crude state, or in combination with other materials, may be heated and reheated to the consistence of thin paste, without injury to its future manufacture. India-rubber, if but once treated in the same manner, will be destroyed and unfit for future use.

Gutta-percha is not decomposed by fatty substances; one application of it is for oil-vessels. India-rubber is soon decomposed by coming in contact with fatty substances.

Gutta-percha is a non-conductor of cold, heat, and electricity, and in its natural state is non-elastic, and with little or no flexibility. India-rubber is a conductor of heat, cold, and electricity, and is highly elastic and flexible.

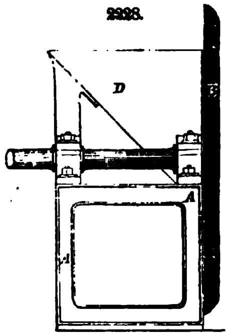
The specific gravity of gutta-percha is much less than that of India-rubber—in the proportion of 100 of gutta-percha to 150 of India-rubber.

Preparation.—The preparation of gutta percha does not materially differ from that of India-rubber. (See INDIA-RUBBER.) The crude material is delivered to commerce in blocks weighing from 2 to 5 lbs. each, filled with impurities. In order to purify it, the blocks are cut into slices by the machine represented in Figs. 2228 to 2230. Fig. 2228 is a side elevation, Fig. 2229 a front elevation, and Fig. 2230 a sectional view. *A A* represents the framework. *B* is a circular iron plate, of about 5 feet diameter, in which are three slots, into which are inserted three radial knives, in a similar manner to the irons of an ordinary plane or spoke-shave. B^1 is a shaft, to the end of which the plate *B* is attached, and by means of which it is made to revolve at any desired velocity, motion being communicated to the shaft from a steam-engine, or any other convenient first mover, through the medium of gearing or drums *D* is an inclined shoot, down which the lumps of crude gutta-percha are dropped against the knives of the revolving plane *B*, by which they are cut into slices of a thickness corresponding to the degree of projection given to the knives. The speed of this machine is about 200 turns per minute. The slices are afterward collected, and put into a vessel filled with hot water, where they are left to soak till they feel soft and pliable to the touch, and until all the leaves and other impurities contained in the mass are separated from it. In this partially purified state the material is taken to a carder, or large circular box containing a cylinder or drum covered with curved teeth. This runs at a speed of about 800 turns per minute, and shreds the gutta-percha into small pieces, which fall into a vat of water placed below. The gum being porous floats on the surface, and the impurities are precipitated.

Another machine for this purpose is represented in Fig. 2231, which subjects the gutta-percha to a very thorough working over. The crude gum is presented by the feeding rollers G^1 to the action

of the first breaker F^1. It is by the latter broken up into shreds or fragments, and considerable quantities of earthy and other extraneous matters are beaten out of and disengaged from it, the whole falling in a mingled mass into the water contained in the compartment t^1 of the tank, where the different materials assort themselves according to their specific gravities. Such pieces as consist of

2228.



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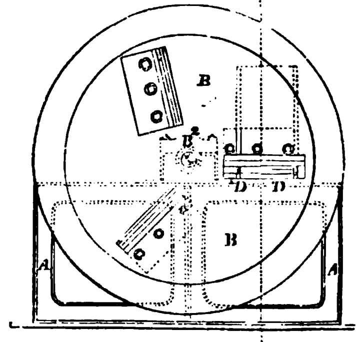

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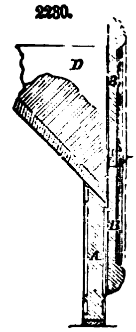
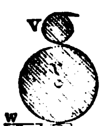
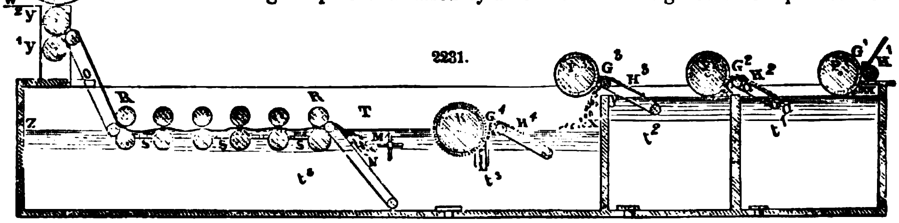


pure gutta-percha, or in which gutta-percha predominates, float on the surface of the water, while most of the earthy and other extraneous matters sink to the bottom. The revolving endless web H^2 then draws toward it the floating gutta-percha, and carries it upward to the second set of feeding-rollers G^2, mounted over the second compartment t^2 of the tank, from which rollers it is delivered to the second breaker F^2, to undergo a repetition of the process which has been just described, in order to its being further disentangled and purified. From the surface of the water in the compartment t^2 the gutta-percha is carried up the inclined endless web H^3 to the rollers G^3, which deliver it to the third breaker F^3 over the compartment t^3, by which it is a third time broken up, in order to separate any remaining impurities from it. The inclined endless web H^4 next carries it forward to the rollers G^4, which present it to the revolving cylinder K, by the blades of which it is cut or minced into a multitude of very thin slivers, which, as they fall into the water in t^3, are thrown forward in the direction of the agitator M. As this agitator revolves in a direction opposite to that in which the floating mass of gutta-percha is moving, it forces the gutta-percha down into the water, and to take a circuitous course through it toward the large endless web N, whereby it is washed free from any dirt which may have collected upon it in passing through the preceding operations. By the endless web N the gutta-percha is next moved onward to the series of rollers $R\,R$, $S\,S$; and from the last pair of the series the gutta-percha is raised by an endless revolving web O to a pair of metal



2231.



pressing and finishing rollers Y^1 Y^2, which are set by adjusting screws to a distance from one another equal to the thickness of the sheet or band into which it is now desired that the gutta-percha should be compressed. After passing through between Y^1 and Y^2, the sheet or band is carried back over the topmost of those rollers, Y^2, and then over the wooden drum U, to be wound on a taking-up roller V. In case it is desired to unite the gutta-percha with cloth, for the manufacture of a water-proof fabric, the cloth is led in as shown at W, and is firmly united to the gum by pressure between the roller Y^2 and drum U. After passing through the carder previously described, the gutta-percha is kneaded and rolled into sheets.

In order to cut the sheet gum into strips or bands of any shape, an ingenious machine devised by Charles Hancock in 1844 is used. It consists simply of two steel rolls grooved on their surface. The grooves on each roll are semicircular, so that when the rolls are superposed a series of cylindrical orifices is formed between them. The material, previously heated, is passed between the rolls, which cut it into cylindrical strips, or strips of any desired shape of section, corresponding with the form of the grooves. Another method of cutting sheets into strips is by the use of a large number of parallel blades mounted on a single moving support.

The form of calenders used in the manufacture of sheet gutta-percha is represented in Figs. 2232 and 2233. The rolls are 6 feet 4 inches long and 22 inches in diameter, each one weighing about 7,000 lbs. They are heated by steam.

Gutta-percha tubes are made by forcing the gum over a steel mandrel held as a core in a cylinder of iron. As the material is hot on emerging, the sides of the tube would naturally stick together. To prevent this, the tube as fast as it is formed is led through a vat of water some 50 feet in length.

The water, pressing equally on the interior as well as the exterior of the tube, keeps it in shape until it cools and sets. By this means a single tube of nearly 1,100 feet in length has been made without a break of any kind.

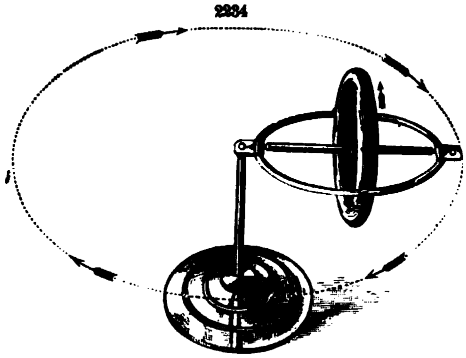
An important utilization of gutta-percha is as an insulating material for electrical conducting-wires. A thin coating of the gum may be applied to a wire by passing the latter through a vessel containing the gutta-percha in a melted state. This method, however, does not answer for applying the gutta-percha envelope to submarine or subterranean cables. For this purpose the gum is purified with the greatest care, and is placed in a cylinder, where it is kept plastic by heat, and at the same time is strongly compressed by a piston. The wires composing the core of the cable are caused to pass through a chamber into which the gum also enters, and at the same time are rotated, so that they emerge covered with a layer of gutta-percha, which is increased in thickness as desired by repetitions of the process.

Vulcanization of gutta-percha is effected in the same manner as that of India-rubber. The operation renders the material much harder, but it is not nearly so necessary to adapt it to various purposes as in the case of caoutchouc; hence it is not often done. The impossibility of working or dissolving gutta-percha or rubber after vulcanization has led to many attempts to remove the sulphur, the most successful of which is noted under INDIA-RUBBER. In vulcanizing gutta-percha, when the proportion of sulphur is increased and the heat prolonged, a very hard black substance is produced, which is susceptible of high polish, and which may be worked like ivory. This is commonly made into combs and various objects of art. Gutta-percha is largely used by dentists as a foundation for artificial dentures.

Works for Reference.—See articles "Gutta-Percha" in Ure's "Dictionary of Arts and Manufactures," and in the "American Cyclopædia." See also Figuier's "Merveilles de l'Industrie."

GYROSCOPE.* A name applied to various instruments designed to illustrate the phenomena of rotation. The most curious and generally interesting form of gyroscope, rightly named "mechanical paradox," Fig. 2234, although its principle was discovered long before its first construction, consists essentially of a disk revolving on pivots within a ring, having on the line of prolongation of its axis, on one side, a bar or spur with a smooth notch beneath to receive the hard smooth point of an upright support. Thus placed, when the disk is not turning, the whole falls, of course, like any heavy body unsupported. Rotate rapidly by unwinding a string, set on the support, but uphold the opposite side of the ring; no peculiar movement then occurs. But if while the disk is rapidly turning, the bar being on the support, the opposite side be set free, the whole, instead of falling, as would be expected, commences a steady revolution in a horizontal circuit about the point of support, moving more rapidly as the primary rotation is expended, and sinking, at first imperceptibly, then more rapidly, until in from one to three minutes it comes to rest. Mathematical analysis shows that when set free it continually falls and rises, but this motion is not visible. The disk started with its axis in or below the horizontal never rises, without aid, above its first position. Started with high speed above the horizontal, it may rise; and if its connection with the support allow, as when this is by a ball and socket, it may even ascend to a vertical position, and spin as a top. Arrested in its traveling movement, it always descends; hastened, it rises. Checked in any part, it inclines in the direction of that part. In the form now given, the traveling or orbital movement is always in the direction in which the bottom of the disk is going. But if the axis be prolonged beyond the support, and the disk and ring slightly overpoised by a weight on the other side, then the disk always travels in the direction in which its top is going, and nearly all the phenomena are reversed. Many other curious results may be obtained; it will here be added further only that the disk below the horizontal is always, and above it usually, slowly falling; and that the orbital motion invariably takes place toward that side of the disk in which the force of the rotation about its own axis is most resisted or checked. For proof of this latter principle, let any small wheel be rotated, and while turning rub or seize it upon any side; the rotation in this side being thus checked, and actually or in effect subtracted from, that in the opposite side preponderates, and the wheel is urged toward the side in which the checking occurs.

2234



Perhaps no completely satisfactory explanation of the phenomena can be given without employing the language and processes of the higher mathematics. This has been done in a very complete manner by Gen. J. G. Barnard in a paper published in the "American Journal of Education" for June, 1857, and also published separately under the title "Analysis of Rotary Motion as applied to the Gyroscope" (New York, 1857). The following explanation, proposed by Dr. Levi Reuben of New York, is perhaps as satisfactory as it is possible to give without the aid of mathematics. There are two facts to be explained: support, and orbital movement, or traveling about the supporting point. For the first, suppose the disk composed of 1,000 equally heavy particles. When it is set rotating and released, each of these particles is, as a separate ball, acted on by two moving forces, that giving the rotation, and that of gravity; but the whole is also held together by the constraining action of cohesion. Suppose that, when released, the axis points below the horizontal: gravity acts in vertical lines and equally on all the particles. Its direction and amount may be represented by equal short pendent threads dropping down from all the particles. If the particles be also supposed in a single plane, the extremities will all lie in a new plane, slightly without and below the plane of the disk, and parallel with it. The forces impressed in giving rotation upon the several particles of the disk will all point in its plane, being represented at any moment by tangents to the circles in which the several particles move, pointing in all directions, and varying in length from the axis, where this is zero, to the periphery, where it is a maximum. But the resultant movements or tendencies of the particles must all terminate in the exact plane in which the gravitative components were seen to terminate. Every particle thus acted upon, then, tends to go outward or forward into the new plane already referred to. The several pressures are to points scattered somewhat widely in that plane; but owing to the cohesion of all the particles, they are constrained to move or press forward in a body. The effect is as if the whole disk were pulled outward and very slightly downward, while the pivot in the notch reacts or pulls in the opposite direction; and the wheel is supported, in part, as if slung up by strings attached to its two faces and pulled in opposite directions. When the disk is above the horizontal, the new plane is behind or within it; it then pushes against the pivot, and, this reacting, there occurs support by opposite pressures, instead of tractions. Thus we discover one reason why no material support is needed for the remote end of the axis; while as a consequence of this view, if the axis be horizontal it must first sink slightly, yet it may be only imperceptibly, before support can occur. This agrees entirely with the results of mathematical analysis.

In the second place, why does the disk travel around the supporting point? When not overpoised,

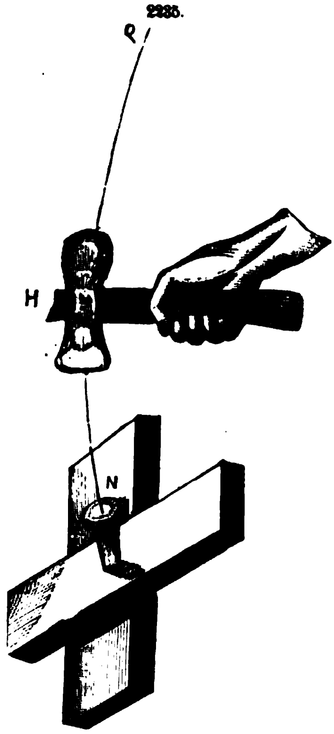
* From the "American Cyclopædia."

gravitation acting downward, and rotation, in the ascending side of the disk, upward, the latter is in effect decomposed into a horizontal and a vertical component, the horizontal expressing itself in the pressure already referred to, the vertical being resisted or antagonized by the force of gravity; the result for each particle being the sum which the latter as a negative quantity would form with the former. In the ascending side, therefore, gravity overbalances, equals, or diminishes, according to the place of each particle, the rotative force of ascent acting upon it; but to the vertical component of the rotative force of all the particles in the descending side it adds alike a quantity of action equal to its own amount. Hence, the whole rotative force in the descending half may be considered as increased, that in the ascending as diminished. There will be some point in the ascending half at which the vertical component of rotation equals gravity; this will become in effect a point of rest, or of no action. This is then the point pierced by the resultant axis—the point about which all the particles under the combined forces will tend to revolve: those in the ascending half starting with less radii to sweep around this point as a centre; those in the descending starting with longer radii, and sweeping in longer curves about the same point. Thus the disk is continually carried to the side in which the action is most checked; and this constitutes the traveling movement. When overpoised on the opposite side, the action of gravity on the disk itself is upward, the axis acting as a lever, the support on which it rests as a fulcrum: the rotative force of the descending particles is now resisted by it; and for a like reason the disk now moves toward its descending side. When not overpoised, the traveling movement of the disk itself introduces a new element into the case, by resisting the rotating of particles in the upper half backward in the course of movement. This checks and diminishes the action in the upper half of the disk, and constitutes a new source of support by generating a tendency upward; and it is doubtless this part of the action that raises the disk at times to an erect position. The principles thus arrived at explain also why the disk travels faster as its axial rotation lessens, and also when weights are added to it; why in the ordinary form it rises if its motion is hastened with the band; why, if overpoised, it descends by being hastened, and rises on being delayed in its orbital movement; and in fact, it may safely be said, every phenomenon which the instrument can be made to present. The same explanation, in effect, applies if the rotating body be a sphere, or of any other form

The facts of support and orbital movement, though separately considered, are really but two different expressions of the same phenomenon; the two actions, here for convenience separated, really conspire in one movement, and that is the composition of a rotation caused by gravity with another imparted by the hand. The reason why the rotating body does not fall is that, in such a body, whenever its plane is oblique to the vertical, gravity is no longer allowed to act singly, but must in every instant enter into composition with another force. Hence the body in such case cannot simply fall, but must move toward such new place in space as the combined actions shall determine; and hence, again, the same force which ordinarily produces a vertical fall, here carries a body round in a horizontal circle, or secondarily sometimes even causes it to ascend. The weight of the rotating disk, however, is in all positions sustained by the support and base on which the apparatus rests. In this explanation, the distance through which the gravitative force acts has been taken as very short, because by experiment and calculation it can be proved that, unless the weight of the ring is very great, the whole downward action of gravity on the disk is very slight compared with that of the rotation first imparted by the hand, sometimes as small as in the ratio of 1 to 40 or 60.

HACKLE. See FLAX MACHINERY.

2235.



HAMMERS, HAND. The nature of work to be done by hammers calls for very great differences, not only in the form, material, and weight of the hammer-head, but also in the appendages to it. There are the material and form of the handle, the angle at which the handle should intersect the axial line of the hammer-head, the position of the centre of gravity with respect to the intersection of this axial line, and the length and elasticity of the handle. If the centre of gravity is not in the central line or longitudinal axis of the hammer-head, then there is a tendency to bring the hammer down on the edge of the face, and not on the face. If this defective construction be great, the muscles of the wrist may not be strong enough to counteract the tendency. If the defective construction be slight, then the work is often marked with angular indents. Arrangements too may be required for modifying the intensity of the blow while retaining the effects resulting from a heavy hammer, where a light one would be inefficient.

In dealing with hammers the following questions claim careful consideration: What power or energy is in a hammer of known weight moving at a known velocity, if brought to a state of rest by impact on a block? Can this impact effect of a hammer be converted into simple pressure, and be stated as a load or weight placed where the impact is requisite to produce the same effect as the impact did? If the mode of solving the first question

be made clear, then the answer to the second can be readily obtained. The measurable elements which affect the result are a variation in the mass of the hammer-head and a variation in the length of the handle. By a varied mass there is a varied weight in the hammer; by a varied length of handle there will, with the same muscular effort, be a varied velocity in this mass; and upon a combination of mass and velocity depends the produced energy. (See DYNAMICS.) Now, if a mass of metal moving at a known velocity strike an object, the energy of the blow results from the conditions at the moment of impact. For example, the work done in the hammer H, Fig. 2235, as it strikes the nail N, does not depend upon its velocity through the arc $Q\ N$, but only upon its velocity when commencing contact with the nail. Hence, so long as the material which gives the blow and the mass of it are the same, it is not of any consequence how the velocity was accumulated. It may result from centrifugal or rectilinear action, or from muscular effort, steam pressure, or gravity. Hence, other elements remaining unchanged, whatever accelerates the velocity of a hammer increases, according to very clear rules, the energy of that hammer.

Custom and certain mathematical considerations have led to the adoption of the height of the fall needful to impart a velocity, rather than the velocity itself, as the element to be combined with the mass of a hammer in order to determine its actual energy. It may therefore be stated that the simple pile-driving machine or drop-hammer, in which the head falls under the action of gravity only, is the representative form into which all hammers must be converted in order to calculate energy. The laws governing falling bodies, explained fully under DYNAMICS, will make clear the principles governing the present case. To estimate the work in the blow of the hammer, the space through which the hammer-head must fall under the influence of gravity, in order to acquire the velocity of impact, must be determined. Then, if this deduced space be combined with the weight in pounds of the hammer, we shall have the measure of the energy of the latter.

Example.—Suppose a hammer-head weighs 2 lbs., and the velocity at the instant of the blow was observed to be at the rate of 25 feet per second: then the space through which under the influence of gravity it must have fallen to acquire this velocity will be $s = \frac{V^2}{2\,g} = \frac{(25)^2}{2 \times 32.2} = \frac{625}{64.4} = 9.7$ feet, or 10 feet nearly. Then the work of one blow of that hammer would be represented by $2 \times 10 = 20$ foot-pounds; that is to say, the blow of this two-pound hammer would produce an effect similar to that of a weight of 20 lbs. falling through a space of 1 foot, or 40 lbs. through 6 inches, or 240 lbs. through 1 inch. The following table, by Major Maitland of the Royal Gun Factories, Woolwich, England, gives a number of valuable experiments and calculations relative to hammers. They were made upon copper cylinders, and the mean from three experiments of the compression of each from one blow of the hammer, described in the first and second columns, is stated in the third; the other columns in the table explain themselves:

Table Showing Force of Hammers.

NATURE OF HAMMER.	Weight of Hammer.	Compression of Copper with One Blow.	Mean Compression.	Equivalent to 80 Lbs. falling Inches.	Blows per Minute.	Hours Worked per Day (exclusive of Stoppages).	Total Work done in One Hour.	Total Work per Day.	Calculated Velocity of Hammer at Impact, Feet per Second.	The Load in Tons which without Impact must have been placed on the Copper Cylinders to produce the respective Compressions in Column 3.
	Lbs.	Inch.	Inch.				Foot-pounds.	Foot-pounds.		
Hand	2	*a*, .145 *b*, .166 *c*, .159	.158	14	(say) 96	8	336,000	2,688,000	43.3	2.0
Light sledge (raised)	11	*d*, .331 *e*, .329 *f*, .314	.325	59	48	4¼	708,000	3,009,000	37.9	4.0
Light sledge (swung)	11	*g*, .325 *h*, .333 *i*, .346	.335	65	43	4¼	780,000	3,315,000	39.3	4.8
Heavy sledge (raised)	26½	*j*, .374 *k*, .376 *l*, .371	.374	98	36	3½	882,000	3,087,000	31.6	5.8
Heavy sledge (swung)	26½	*m*, .376 *n*, .374 *o*, .377	.376	100	36	3½	900,000	3,150,000	32.0	6.0

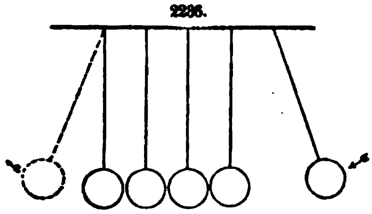
Internal Effects of Hammering on Metals.—Besides the surface work produced by hammers, there is some hitherto mysterious and as yet uninvestigated internal work done by them. If an iron bar be held in the line of the dip of the magnetic needle and struck upon the upper end with an ordinary hammer, it will become polarized, one end repelling, the other end attracting, the magnetic needle. Reverse the bar and strike it on the opposite end as many blows as before were given, and both ends will attract the magnet. Give two or three more blows, and the bar shows magnetic effects the reverse of those first obtained. Something, therefore, has occurred in the bar due to hammer-impact, and the recognition of this makes it in a measure apparent why the compass needle in iron ships may be affected in consequence of the tremor to which the vessel is subjected owing to blows from the waves.

These magnetic manifestations seem to be accompanied with internal material changes, which sometimes make their existence too clear by fractures as unexpected as they are dangerous. In the Engine Works at Crewe, England, numerous investigations have been made into the consequences of blows as from hammers upon cold metals. In one case an axle of a locomotive tender, with its wheels, was subjected to a series of blows, which were successive, periodic, and adjusted. The dimensions of the axle were 6 feet 11½ inches long and 5¾ inches diameter where the wheel was keyed on. It projected 8¼ inches beyond the wheel. A weight of 60 lbs. was caused to fall from a height of 5 feet upon the same part of the axle. In the case of an iron axle, a crack manifested itself after 6,128 blows, and the axle was broken by 9,843 blows. When the axle was of steel and of the same dimensions, the weight struck 50,000 blows from a height of 5 feet. Afterward 3,040 blows were given by the same weight falling from a height of 10 feet; and then the axle broke in two pieces. It is remarkable that in this case there were no previous signs of injury, the sound caused by the blow previous to that which fractured the axle being as clear in its ring as that emitted by the first blow struck. Calculated according to the principle already detailed, the measure of the energy expended before the iron axle cracked is represented by $6{,}128 \times 60 \times 5 = 1{,}838{,}400$; and after being cracked and before the fracture by $3{,}715 \times 60 \times 5 = 1{,}114{,}500$; making a total energy of 2,952,000. Now, before the steel axle was fractured there was expended upon it first an energy represented by $50{,}000 \times 60 \times 5 = 15{,}000{,}000$, and this was succeeded by $3{,}040 \times 60 \times 10 = 1{,}824{,}000$; i. e., before the fracture the steel axle was subjected to a total energy of 16,824,000, or to about 9 times the hammering given to the iron before the latter cracked.

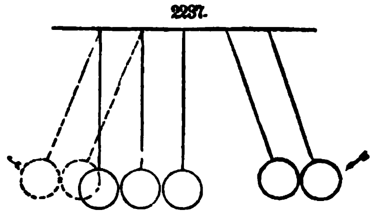
Effects of Heavy and Light Hammers.—An inquiry of much interest with respect to hammers is: What difference is produced on a material if struck by a light hammer moving at a high velocity, and by a heavy hammer moving at a low velocity? For example: Suppose a hammer weighing 2 lbs. strikes an object with a velocity of 40 feet per second; then the height from which that hammer must have fallen under the action of gravity only would be 24.845 feet. The work done would therefore be represented by $2 \times 24.845 = 49.690$ foot-pounds—say 50. Again, suppose a hammer weighing 10 lbs. strikes the same object with a velocity of 18 feet per second; then the height from which that hammer must have fallen under the action of gravity only would be 5.0311 feet. The work done therefore would be represented by $10 \times 5.0311 = 50.311$, or say 50 again.

The two hammers are thus said to have the same amount of work in them, or to be capable of doing equal work. Yet in practice their effects are by no means identical. It is a well-known experimental fact in mechanics that if a series of balls be suspended as shown in Figs. 2236 and 2237, and if one ball *A* be lifted and allowed to strike the row of balls, no matter what the velocity of that ball may be, but one ball will be caused to swing off at the opposite side *B*. If two balls be lifted

2236.

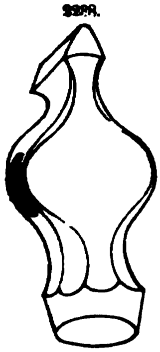


2237.

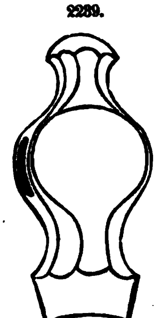


and allowed to swing against the rest, as in Fig. 2237, then two balls will be thrown off at the other end; and so on. No increase of velocity will alter the corresponding number of balls thrown off at the opposite side, though it will the distance these balls travel. Now let the balls in line represent the atoms or molecules of a body: the impinging balls will be hammers of different masses. The

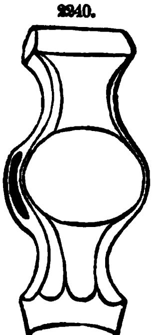
2238.



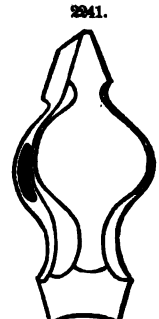
2239.



2240.



2241.

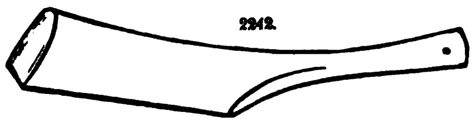


heavy hammer, so to speak, transfers its mass into the interior of the struck object, while the lighter hammer, acting on the same principle, does not put so much of the material in motion. In the case of riveting, it may be inferred that by the use of a heavy hammer the hot, soft rivet might be made to fill in the recesses of the rivet-hole, while the lighter hammer would simply close over and finish off neatly the hammered end, without a cup-swage being put over it. Similar considera-

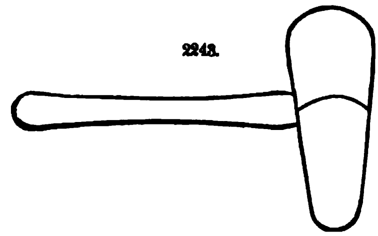
tions to the foregoing underlie the use of light and heavy projectiles fired at high and low velocities from cannon.

Forms of Hammers.—Figs. 2238 to 2241 are different forms of engineers' hammers, varying chiefly in the form and angle the pene makes to the head. Figs. 2242 to 2245 are plumbers' hammers, Fig. 2242 being used both as a hammer and as a swage. Fig. 2246 is a mason's hammer. Figs. 2247 and 2248 show the forms used by boiler-makers. Fig. 2249 is a cooper's hammer, and Fig. 2250 a ship-carpenter's claw-hammer. Fig. 2251 is a coach-trimmer's, and Fig. 2252 a slater's hammer. Fig. 2253 is a fireman's hatchet or tomahawk hammer, and Fig. 2254 is a carpenter's

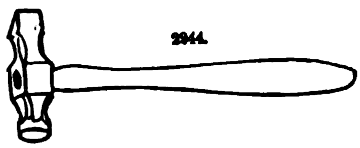
2242.



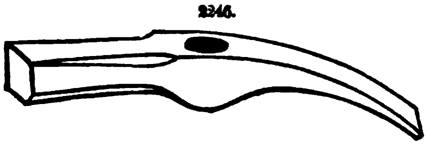
2243.



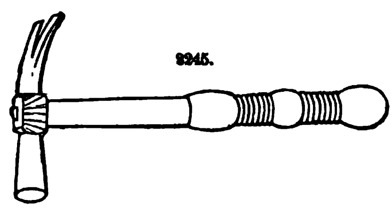
2244.



2246.



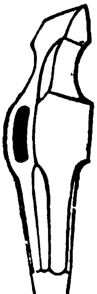
2245.

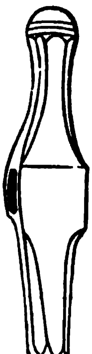


mallet, which should be made of hickory, the sizes being, one $2\frac{1}{2} \times 3 \times 5$ inches long, and another about $3 \times 3\frac{1}{2} \times 5\frac{1}{2}$ inches long, the handles being mortised and properly wedged to the head.

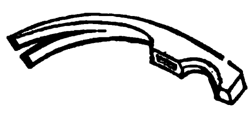
Manipulation of the Hammer.—The operations performed by the hammer may be classified as: 1, driving; 2, bending; 3, stretching or expanding. The first two are comparatively rude operations, but in the last named the exercise of unusual skill and judgment is required. When stretching by means of the hammer is resorted to for the purpose of altering the form of work to bring it to a required form, regardless of straightness and flatness, it is termed "pening," or sometimes "paning;" when flatness or truth is the end sought, the operation is termed straightening. In pening, very light strokes are given, so as to cause the effects of the blows to remain at or near the surface of the metal. But in straightening, heavier blows are delivered, and the effects penetrate the work correspondingly to a greater depth. The principle involved in the operation of pening is that of stretching the surface receiving the blows, which causes the pened surface to lift above the plane of

2247. 2248.

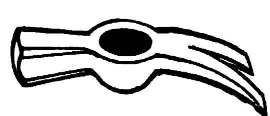




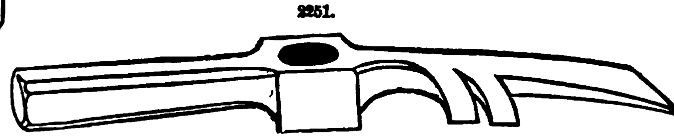
2249.



2250.



2251.

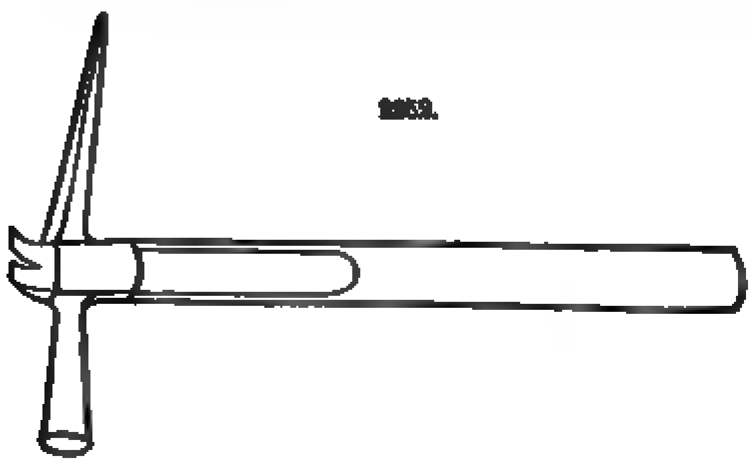


the original surface. Thus, suppose a plate of iron to be bent as shown in Fig. 2255. The delivery of light blows, as denoted by the small circles at *A*, would stretch that side of the plate without affecting the opposite surface, and by elongating it cause the plate to straighten; or if the pening were sufficient, the plate would become bent in the opposite direction, the convex surface becoming the concave one.

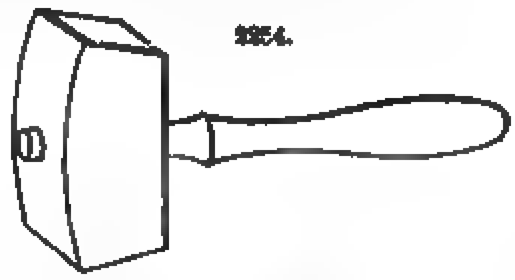
The hammer used by plate-straighteners and saw-straighteners, shown in Fig. 2256, is termed a "long cross-face"—"long" because, being intended to be used as a sledge, it is provided with a long handle, and "cross-face" because the length of the face on one end stands crosswise with the

length of the face on the other. This hammer causes the metal to rise or lift in front of it, the direction in which the rise takes place depending upon the direction in which the length of the hammer-face strikes the plate. Suppose, for example, that we strike the blows shown at the end A of the plate shown in Fig. 2257, and that we then turn the hammer upside down and strike the blows

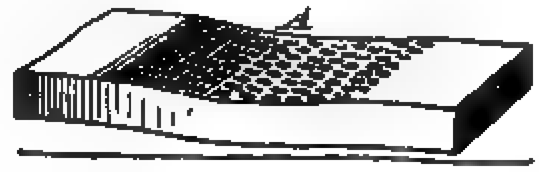
2252.



2254.

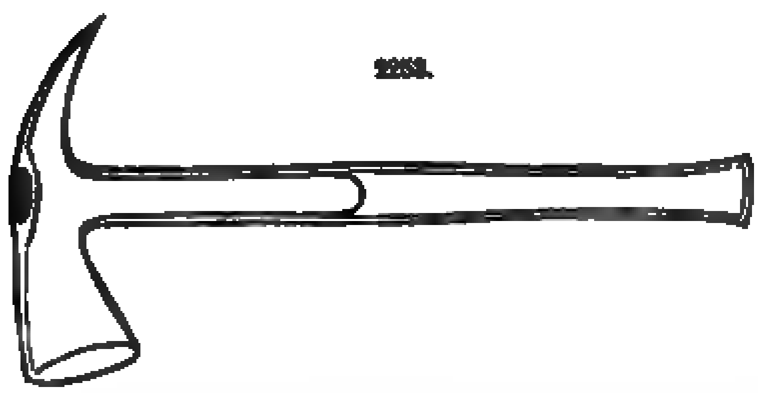


2255.



2256.

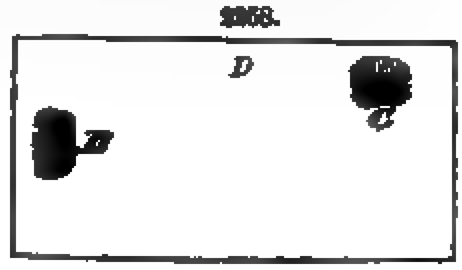
2253.



denoted by the marks at B in the same figure (this the workman can perform by reversing the hammer, without changing his position); the result will be to curl up the plate as denoted by the dotted lines. This effect is produced by two causes, the first of which is the shape of the hammer-face, and the second is the direction in which the blows fall. Fig. 2258 represents an iron plate

2257.

2258.



with one each of the blows shown in Fig. 2257 delivered upon it at B and C. Then, the indentation of the plate being denoted by the full line, the tension caused to the surrounding iron will be indicated by the dotted lines. It will be noted that these dotted lines are in each case longer on one side of the mark than on the other; and the reason is that the effect is greater on that side, or rather in that direction, because the hammer does not fall vertically upon the plate, but somewhat aslant. If the plate shown in Fig. 2257 be turned up on edge so as to appear as in Fig. 2259, the direction in which the hammer would travel when striking the blows at A in Fig. 2257 is denoted by the arrows B in Fig. 2259; while if we turn up the same plate so that its edge D in Fig. 2258 will appear as the edge D in Fig. 2260, the direction of the blows shown at B in Fig. 2257 will be denoted by the arrows B in Fig. 2260; so that both the shape of the hammer-face and the direction of the blow conjointly act to draw or bend the plate in the required direction. If we take a ball-faced hammer, the effect produced will be as shown in Fig. 2261, in which the circle A represents the mark left by a ball-face or pene hammer, and the diverging dotted lines show the effect of the blow upon the surrounding iron. B represents a blow delivered by the same hammer, which while falling traveled also in the direction of the arrow C, the direction effects of the blow being denoted by the dotted lines.

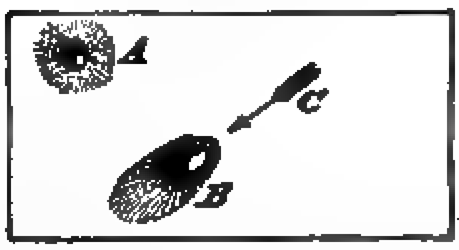
We next come to the twist-hammer, shown in Fig. 2262. This is a hand-hammer with the two faces standing parallel to each other, but diagonal to the body of the hammer; so that, by turning the handle in the hand, the direction of the hammer-marks will be reversed. Suppose, for example, that in Fig. 2263 the outlines represent a plate; the lines slanting one way, as at A, will represent hammer-marks made by one face, and those slanting the other way, as at B, marks made by the other face of the hammer, the direction or line in which the hammer fell being the same in both cases. By very little moving of the position of the hammer-handle, then, and by turning the hammer as required, the workman can place the hammer-marks in any necessary direction, as shown by

the remaining marks in Fig. 2263, without needing to change his position. The iron-worker often employs this means to alter the form of girder-rods, shafts, etc., that are too rigid to be bent by ordinary hammer-blows, as well as to close and refit work. Suppose, for instance, the strap shown

2259.

2260.

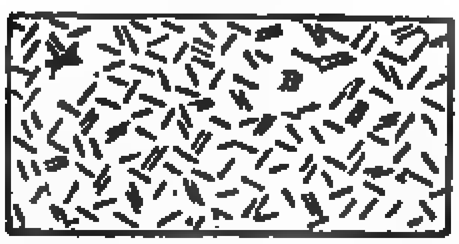
2261.



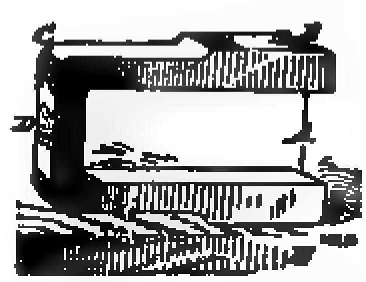
2262.

in Fig. 2264 was too wide at A. It may be rested on a bench or wooden block E and pened at the corner C. If, however, the strap had a sharp instead of a round corner at C, it would be necessary to rest the two ends of the strap-jaws on the bench, and, using the ball pene, deliver the blows shown by the marks at D. In either case, the effect will be to close the distance between the jaws at A. The reason in the latter case for pening the strap in the middle is that, since the pening will tend to round the face lengthwise, filing out the pening marks will tend to straighten that face, and may be more quickly performed; for, if we were to pene the face in two places, the filing out of the marks would aid the pening to round the face. It is obvious that, were the jaws too narrow at A, pening the inside crown face of the strap would widen them. The blows should fall dead; that is, the hammer should fall, to a great extent, by its own weight, the number rather than the force of the blows being depended upon; hence the hammer-marks will not be deep. This is of especial im-

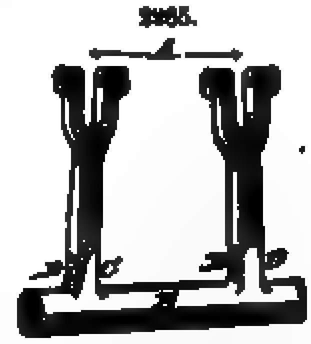
2263.



2264.



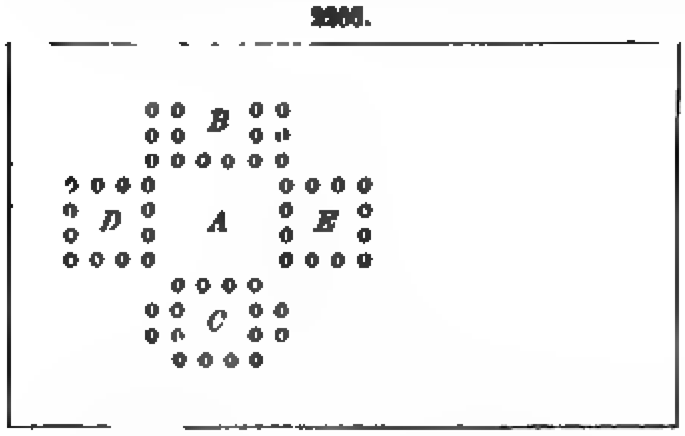
2265.



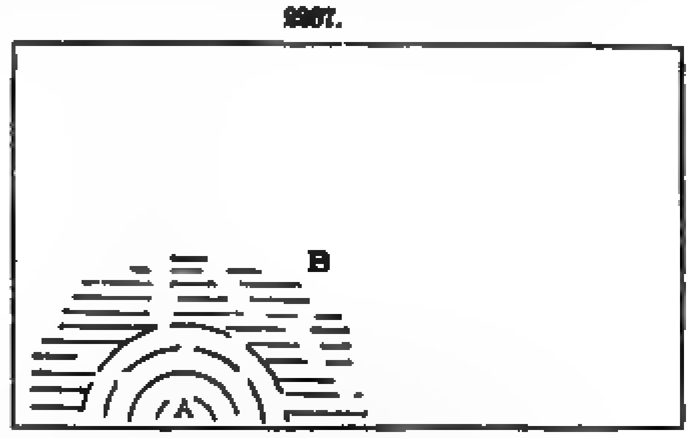
portance when pening has to be performed upon finished work, because, if the marks sink deeply, proportionately more grinding or filing is required to efface them; and for this reason the force of the blows should be as near equal as possible. Another and a more important reason, however, is that the effect of the pening does not penetrate deeply; and if much of the pened surface is removed, the effects of the pening will be also removed; for, as a rule, the immediate effects of the blows do not penetrate deeper than about one-thirty-second of an inch. While the work is being pened, it should be rested upon a wood or a lead block, and held so that the part struck is supported as much as possible by the block. In no case should it be rested upon an iron or any hard-metal block, as that would tend to stretch the under face, and partially nullify the effects of the pening.

In straightening work of cast-iron, pening bears an important part, especially in the case of iron patterns or light iron castings. Suppose, for example, that Fig. 2265 represents an iron casting, and

2266.



2267.

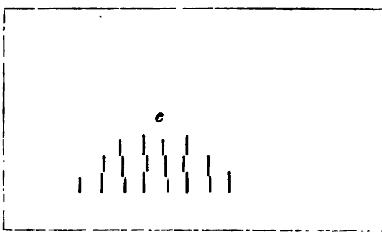


that the distance A from the centre of one double eye to that of the other was too short; by pening the arms on the faces denoted by B, C, and in the place denoted by B, the distance A could easily be made correct. If the width at A were too great, similar pening at C, D would be required.

The skill demanded in the straightening processes consists not so much in delivering the blows as

in discovering precisely where they should be delivered, because one misdirected blow increases the error in the plate and entails the necessity of many properly delivered ones; and though the whole plate may be stiffened by the gross amount of blows, yet there will be created local tensions in various parts of the plate, rendering it very likely to spring or buckle out of truth again. If, for example, we take a plate of iron and hammer it indiscriminately all over its surface, we shall find it very difficult to straighten it afterward, not only on account of the foregoing reasons, but for the additional and most important one that the effect of the straightening blows will be less, on account of the hammered surface of the plate offering increased resistance to the effects of each blow; and after the plate is straightened, there will exist in it conflicting strains, an equilibrium of which holds the plate straight, but the weakening of any of which will cause the preponderance of the others to throw the plate out of straight. To discover where it is necessary to apply the hammer, the operator (if it is a thin plate) rests one end on the straightening block or anvil, and supports the other end with one hand while with the other he bends the plate. The unduly expanded parts of the plate then show themselves by their excessive movement under the bending process, and for this reason are called *loose places;* while the unduly contracted parts, which are called *tight places*, offer more resistance to the movement, and therefore move less. The operator requires to observe, besides the location, the shape of the loose place, so that he may know in what direction the length of the hammer-face should meet the plate to stretch the tight places in the proper direction. If the plate is too heavy and strong to be tested by springing it with the hand, it is held or rested on edge, when the shadows upon its face disclose the expanded and contracted places. In either case the hammer is similarly applied. An example is shown in Fig. 2266, in which A is supposed to represent a loose place, and B, C, and D tight places. The hammer is therefore applied at B, C, and D, as denoted by the small circles. This process, however, induces a tight place at E, which is also hammered.

2268.



In Figs. 2267 and 2268 is shown the process for removing kinks or bends at the edge of the plate, the circular lines at A denoting a loose place. The hammer is first applied as at B; the plate is then turned over and hammered as at c in Fig. 2268, the lengths of the hammer-marks being in the direction shown.

A valuable paper on the hammer, by the Rev. Arthur Rigg, from which extracts are made in this article, appears in the *Journal of the Society of Arts*, xxiii., 813. J. R. (in part).

HAMMERS, POWER. Of these machines there are three principal types: 1. Drop-hammers, in which the hammer is lifted and afterward allowed to fall by its own gravitation, delivering its blow after the manner of a pile-driver. 2. Trip-hammers, in which the hammer is lifted by a cam against the compression of a spring or elastic cushion, which accelerates the fall of the hammer, and hence the force of the blow delivered, when the hammer arm or beam is released from the action of the cam. 3. Dead-stroke hammers, in which the connection between the hammer and the mechanism driving it is made elastic, so as to enable the hammer on its descent to increase in velocity independently of the speed of the mechanism, and also designed to prevent the full shock due to the blow from being imparted to the frame and other portions of the machine. To this last class belong the pneumatic hammers.

DROP-HAMMERS have become almost indispensable for the manufacture of small articles of iron and steel, such as parts of sewing-machines and fire-arms. They operate in connection with properly made matrices and dies, reproducing almost indefinitely the form in its exactness, and leaving the material in excellent shape for subsequent working. Drop-dies are usually made of refined cast-steel, and they are often strapped with tough wrought-iron shrunk on after the dies are otherwise finished.

Merrill's Drop-Hammer is represented in perspective in Fig. 2269. The operating mechanism is shown in section in Fig. 2270. The hammer-head, which weighs from 300 to 1,800 lbs., is attached to a board of white oak B, which passes up between two smooth friction-rolls A in the upper portion of the machine. These rolls revolve in opposite directions. The shaft upon which the front roll is keyed runs in eccentric sleeves, one of which is shown at C, placed in stationary boxes. When these sleeves are rotated a small portion of a circle, the front roll is moved nearer to or farther from the rear roll, and this movement is effected by the operator by means of the rod D, which is connected with a treadle. When the rolls are closed together and pressed against the board, their friction on each side of the latter raises it, and thus elevates the hammer; then, when the rolls are separated, the head is free to fall by its own gravity. On the right of the machine, Fig. 2269, is shown a latch which is connected with the treadle, and which may be pivoted at any elevation. On this the hammer rests in the beginning, and when the workman presses down the treadle he pulls back this latch, and at the same time through the rod D separates the rolls. The hammer then falls. The instant the blow is delivered, the operator removes his foot from the treadle, the drop-rod then falls, and the eccentric sleeve turning the front roll, aided by the pull of the belt, is forced against the board, raising the hammer up again. If it be desired to give a series of heavy blows, the latch is thrown back, and the hammer is allowed to rise until it strikes a projection on the drop-rod. It thus lifts the latter, causes a separation of the rolls, and falls. By this arrangement the hammer may be made to follow the motion of the foot, and blows of any degree of lightness or shortness may be given.

The Hotchkiss & Stiles Drop-Hammer.—The working portions of this hammer are represented in

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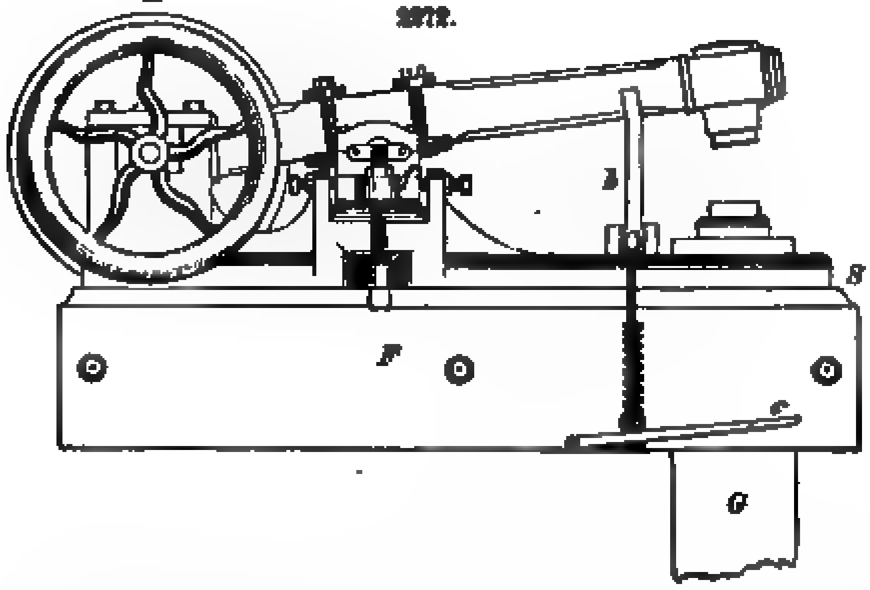

Fig. 2271. A board is attached to the head, as in the preceding example, and passes between friction-rolls. Motion from one to the other of the latter is communicated by cog-wheels *B*. The teeth are always engaged, and hence the revolution is constant; but in order to cause the griping of the board, the shaft of one wheel, and consequently the roll thereon, is moved closer to the other. The teeth of the wheels are sufficiently long to admit of this movement. This sliding motion is effected

by an eccentric C connected with a lever D. Clamps G are provided to enable the operator to hold the hammer at will.

In making drop-forgings, the metal is heated and placed in the lower die, but not in such a quantity as to fill the latter. As the drop falls the blow forces the material into all the recesses of the mould, of which the exact shape is reproduced. It is quite common to place the hot metal above the die and drive it down, doubling it up, so to speak. This is bad practice, as the air in the die becomes tremendously compressed, and forces its way out, scoring the cast-steel of the latter almost

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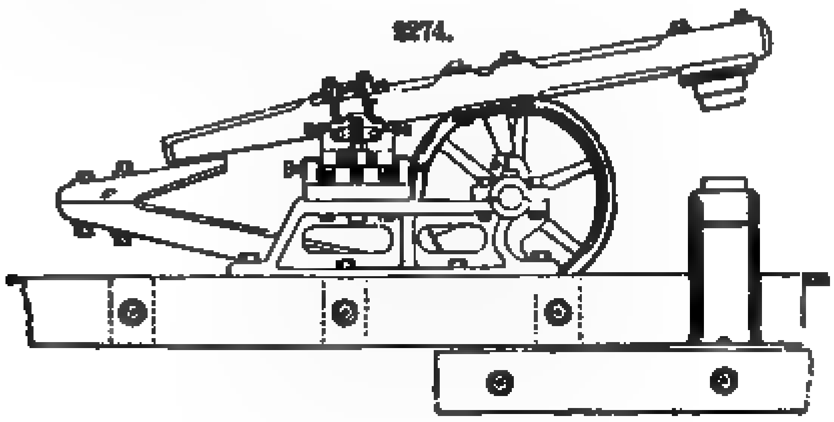

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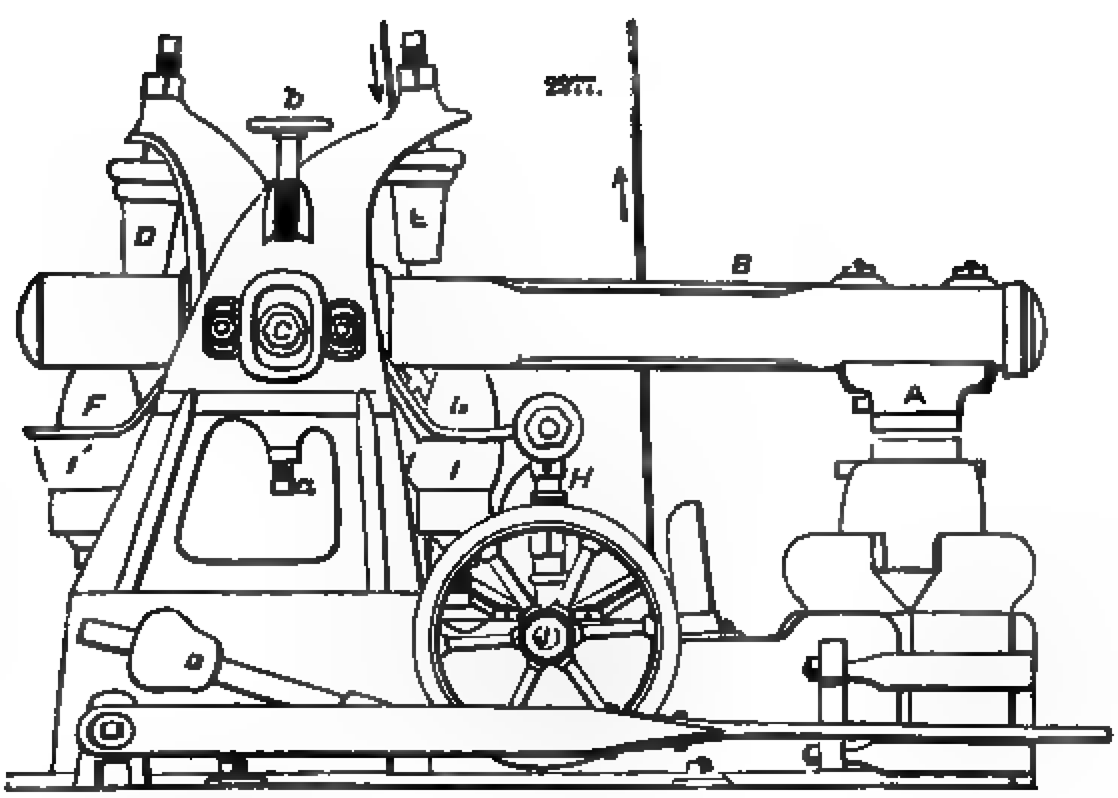

as sharply as if done by a file. Again, but a single blow should be delivered, as the first stroke usually spreads out a thin sheet of metal on the surface of the die, which rapidly cools. If this be struck by the hammer, not only will the forging be thrown out of shape, but the die itself is liable to be injured.

TRIP-HAMMERS.—Figs. 2272 and 2273 represent a small trip-hammer, such as is commonly used in forging spindles and bolts, and for swaging various other kinds of small work. *A* is the driving-pulley, with a flange on each side to guide the belt while running loose. This pulley is attached to the cam-shaft, upon the other end of which is the balance-wheel *E*. *c* is a foot-lever, connected with the catch *b* by a rod and spring, by means of which the hammer can be stopped or started without shipping the belt. *F* is a bed of timbers bolted together to form a support. *G* is the post in which the hammer-block is placed, and usually extends 4 or 5 feet into the ground. *f* is the rocker, adjusted by screws and bolts, so that the hammer can be set at any taper. *S* is a heavy cast-iron plate to which all other parts are connected, and which is bolted firmly to the timbers below.

Figs. 2274 and 2275 represent another form of trip-hammer, in which *b* is the lifting-cam.

DEAD-STROKE HAMMERS.—*The Palmer Power-Spring Hammer* is shown in Fig. 2276. The hammer slides in guides provided in the frame, motion being given to it by means of a spring pivoted at its centre and operated by a crank and connecting-rod, as shown.

The Bradley Cushioned Hammer is shown in Fig. 2277. The upper hammer *A* is bolted to the tube *B*, which passes through, and is carried by a casting pivoted at *C* in bearing-blocks which may be adjusted in height (by means of the set-screw *a* and hand-wheel *b*) so that the face of the upper hammer may meet the face of the work fair, notwithstanding variations in its thickness. Pivoted also at *C* is a triangular frame having the two sockets *I I* for the reception of rubber cushions or springs *F G*. This frame receives motion from the connecting-link *H*, to which it is pivoted. *H* receives motion from an eccentric upon the shaft *J*. As this frame lifts, it throws the tube against the rubber cushion *E*, which causes the motion of *B* to be reversed with considerable force.

PNEUMATIC HAMMER.—Fig. 2278 represents a sectional view of the air-cylinder of an improved atmospheric hammer invented by M. Chenot, and exhibited at the French International Exposition of 1878. When the crank *A* rises, it draws with it the pistons *B* and *C*. Piston *B* causes an expansion in chamber 1. Piston *C* compresses the air in chamber 2, and produces expansion or partial vacuum in chamber 3. These effects unite to cause the entire cylinder *D* to rise, thus elevating the hammer *E*. The cylinder *D* continues its rapid upward motion until the crank passes the point *F*. Then the combined action of the ascending cylinder and descending pistons produces a strong compression of the air in chambers 1 and 3, and this air expanding drives down the cylinder and hammer with great force upon the anvil. Without the interposing air-cushion which always exists between the working parts, it is evident that this machine would be subject to severe and injurious shocks; but these seem to be avoided by the means stated. The movement of the hammer is controlled by mechanism connecting with the brake *G*.

HAMMERS, STEAM, DIRECT-ACTING. The conditions fulfilled by steam as a driving medium for hammers are summed up by Mr. J. Richards, in his "Workshop Manipulation," as follows: 1. The power is connected to the hammer by means of the least possible mechanism, consisting only of a cylinder, a piston and slide-valve, induction-pipe, and throttle-valve; these few details taking the place of a steam-engine, shafts, belts, cranks, springs, pulleys, gearing—in short, all such details as are required between the hammer-head and the steam-boiler, in the case of power hammers. (See HAMMERS, POWER.) 2. The steam establishes the greatest possible elasticity in the connection between a hammer and the driving-power, and at the same time serves to cushion the blows at both the top and bottom of the stroke, or on the top only, as occasion may require. 3. Each blow given is an independent operation, and can be repeated at will, while in other hammers such changes can only be made throughout a series of blows by gradually increasing or diminishing their force. 4. There is no direct connection between the moving parts of the hammer and the framing, except lateral guides for the hammer-head; the steam being interposed as a cushion in the line of motion, this reduces the required strength and weight of the framing to a minimum, and avoids positive strains and concussion. 5. The range and power of the blows, as well as the time in which they are delivered, are controlled at will; this constitutes the greatest distinction between steam and other hammers, and the particular advantage which has led to their extended use. 6. Power can be transmitted to steam-hammers through a small pipe, which may be carried in any direction, and for almost any distance, at a moderate expense, so that hammers may be placed in such positions as will best accommodate the work, and without reference to shafts or other machinery. 7. There is no waste of power by slipping belts or other frictional contrivances to graduate motion; and finally, there is no machinery to be kept in motion when the hammer is not at work.

Steam-hammers are divided into two classes—one class having the valves moved by hand, and the other with automatic valve movement. The action of steam-hammers may also be divided into what are termed elastic blows and dead blows. In operating by elastic blows, the steam-piston is cushioned at both the up and down stroke, and the action of a steam-hammer corresponds to that of a helve trip-hammer, the steam filling the office of a vibrating spring; in this case a hammer gives a quick rebounding blow, the momentum being only in part spent upon the work, and partly arrested by cushioning on the steam in the bottom of the cylinder under the piston. Apart from the greater rapidity with which a hammer may operate when working on this principle, there is nothing gained, and much lost; and as this kind of action is imperative in any hammer that has a "maintained or positive connection" between its reciprocating parts and the valve, it is perhaps fair to infer that one reason why most automatic hammers act with elastic blows is either because of a want of knowledge as to a proper valve arrangement, or the mechanical difficulties in arranging valve-gear to produce dead blows. In working with dead blows, no steam is admitted under the piston until the hammer has finished its down stroke, and expended its momentum upon the work. So different is

the effect produced by these two plans of operating, that on most kinds of work a hammer of 50 lbs. working with dead blows will perform the same duty that one of 100 lbs. will when acting by elastic or cushioned blows. This difference between dead and elastic strokes is so important, that it has

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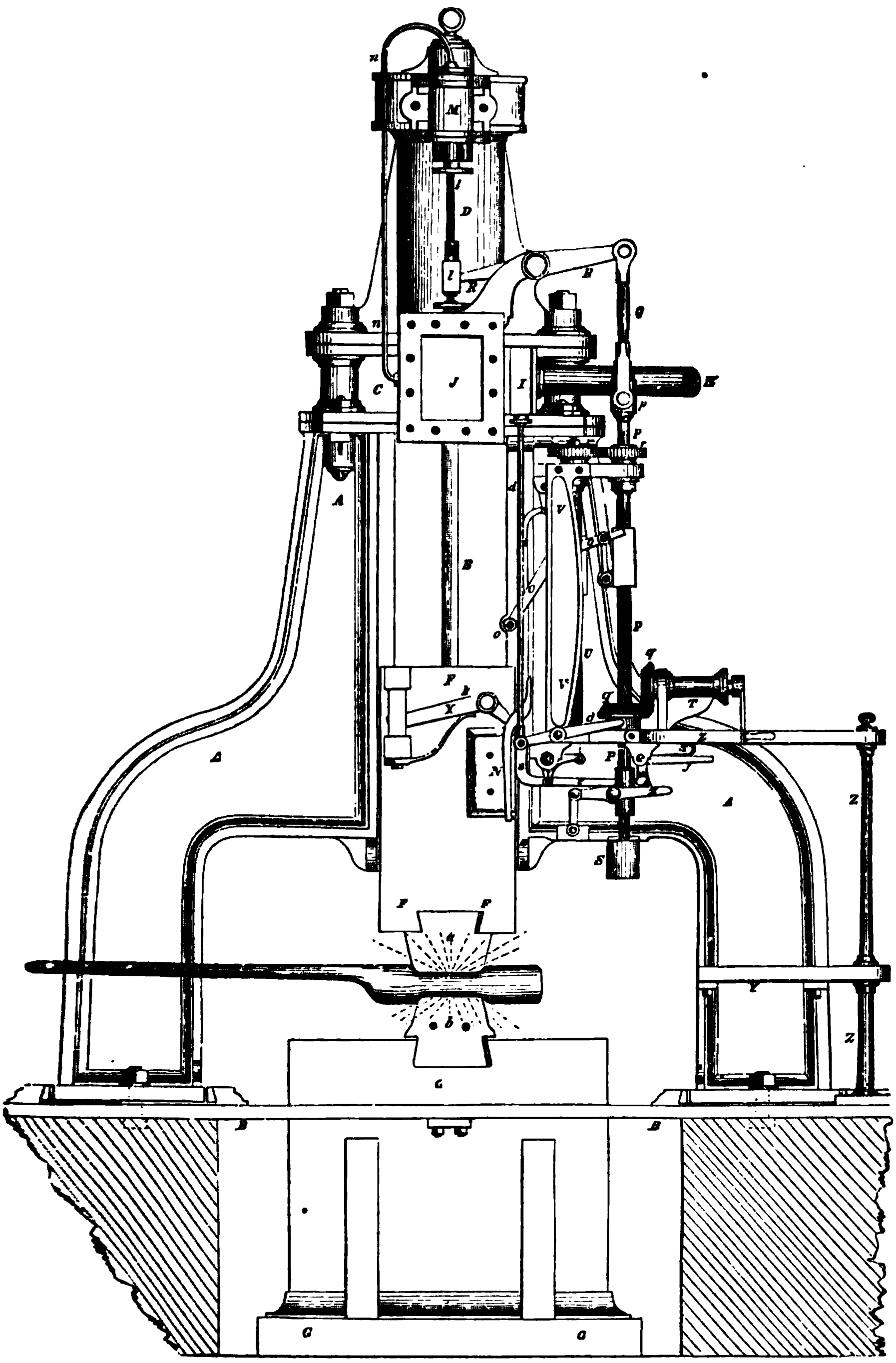

served to keep hand-moved valves in use in many cases where much could be gained by employing automatic-acting hammers.

Some makers of steam-hammers have so perfected the automatic class, that they may be instantly

changed so as to work with either dead blows or elastic blows at pleasure, thereby combining all the advantages of both principles. This brings the steam-hammer where it is hard to imagine a want of further improvement. The valve-gearing of automatic steam-hammers, to fill the two conditions of allowing a dead or an elastic blow, furnishes one of the most interesting examples of mechanical combination. It was stated that to give a dead or stamp stroke, the valve must move and admit steam beneath the piston after the hammer has made a blow and stopped on the work, and that such a movement of the valve could not be imparted by any maintained connection between the hammer-head and valve. This problem is met by connecting the drop or hammer-head with some mechanism which will, by reason of its momentum, continue to move after the hammer-head stops. This mechanism may consist of various devices. Messrs. Massey in England, and Messrs. Ferris & Miles in this country, employ a swinging wiper-bar, which is by reason of its weight or inertia retarded, and does not follow the hammer-head closely on the down stroke, but swings into contact and opens the valve after the hammer has come to a full stop. By holding this wiper-bar continuously in contact with the hammer-drop, elastic or rebounding blows are given; and by adding weight in certain positions to the wiper-bar, its motion is so retarded that a hammer will act as a stamp or drop. A German firm employs the concussion of the blow to disengage valve-gear, so that it may fall and effect this after-movement of the valves. Other engineers effect the same end by employing the momentum of the valve itself, having it connected to the drop by a slotted or yielding connection, which allows an independent movement of the valve after the hammer stops.

Another principle to be noticed in connection with hammers and forging processes is that of the inertia of the piece operated upon—a matter of no little importance in the heavier kinds of work. When a piece is placed on an anvil, and struck on the top side with a certain force, the bottom or anvil side of the piece does not receive an equal force. A share of the blow is absorbed by the inertia of the piece struck, and the effect on the bottom side is, theoretically, as the force of the blow, less the cushioning effect and the inertia of the pieces acted upon. In practice this difference of effect on the top and bottom, or between the anvil and hammer sides of a piece, is much greater than would be supposed. The yielding of the soft metal on the top cushions the blow and protects the under side from the force. The effect produced by a blow struck upon hot iron cannot be estimated by the force of the blow; it requires, to use a technical term, a certain amount of force to "start" the iron, and anything less than this force has but little effect in moving the particles and changing the form of a piece.

Another object gained by equal action on both sides of large pieces is the quality of the forgings produced, which is generally improved by the rapidity of the shaping processes, and injured by too frequent heating. To attain a double effect, and avoid the loss pointed out, Mr. Ramsbottom designed what may be called compound hammers, consisting of two independent heads or rams moving in opposite directions, and acting simultaneously upon pieces held between them. It would be inferred that the arrangement of these double-acting hammers must necessarily be complicated and expensive, but the contrary is the fact. The rams are simply two masses of iron mounted on wheels that run on ways, like a truck, and the impact of the hammers, so far as not absorbed in the work, is neutralized by each other. No shock or jar is communicated to framing or foundations, as in the case of single-acting hammers that have fixed anvils. The same rule applies in the back stroke of the hammers, as the links which move them are connected together at the centre, where the power is applied at right angles to the line of the hammer movement. The links connecting the two hammers constitute, in effect, a toggle-joint, the steam-piston being attached where they meet in the centre. The steam-cylinder which moves the hammers is set in the earth at some depth below the plane upon

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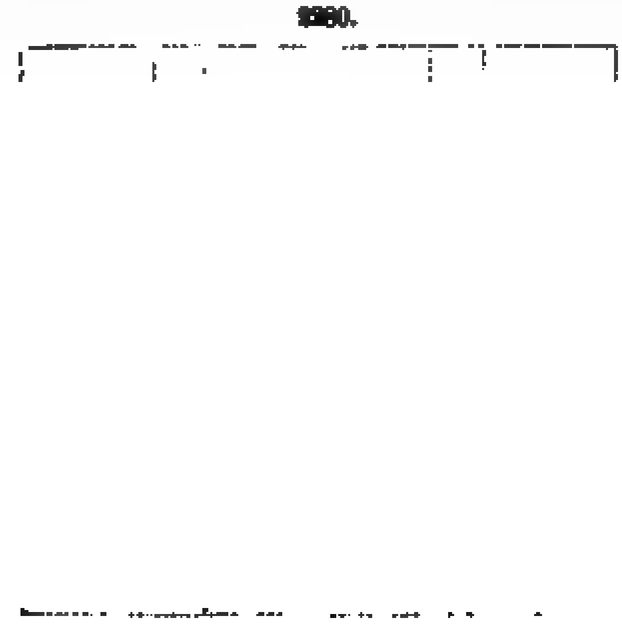


which they move, and even when the heaviest work is done there is no perceptible jar when one is standing near the hammers, as there always is with those which have a vertical movement and are single-acting.

The Nasmyth Steam-Hammer is one of the best-known forms of this machine. In Fig. 2279 the hammer-block, valve-gear, and other working parts are disposed in the positions which they occupy at the termination of a stroke. Fig. 2280 is a general plan corresponding to the above.

Fig. 2281 is an end elevation, and Fig. 2282 a vertical transverse section of the machine.

Fig. 2283 is a sectional elevation of a portion of the machine, showing the positions of the hammer-block, valve-gear, and other working parts when the hammer is raised for a fresh stroke.

The framing of the steam-hammer consists of two strong cast-iron standards $A\,A$, bolted and

2281. 2282.

further secured by keys to a broad base-plate $B\,B$, imbedded in the solid masonry forming part of the floor of the forge. The standards are surmounted, and their upper extremities united, by a species of entablature C, in which the steam-passages and valve-face are formed, and to the upper surface of which the steam-cylinder D is bolted. The piston-rod E is fitted to work vertically through a stuffing-box in the centre of this entablature, and its lower extremity is directly attached to the mass of cast-iron F, forming the hammer-block, which is guided to a strictly vertical and rectilinear course by being made to work freely in planed guides formed on the interior surfaces of the standards $A\,A$. The hammer a itself is inserted into a dovetail recess in the bottom

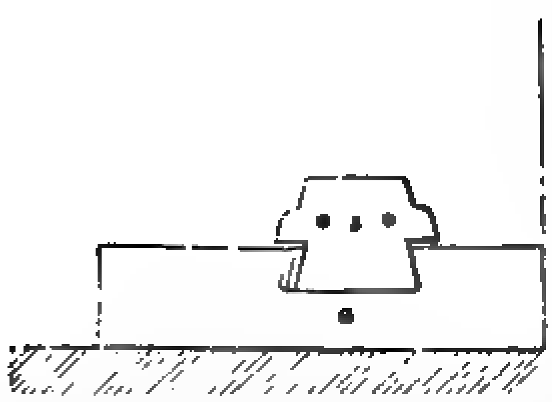
of the block *F*, where it is retained by a wooden packing and iron wedges; while the anvil *b* is in a similar manner secured to the anvil-block *G*.

Steam is led to the machine by the steam-pipe *H;* a throttle or shut-off valve *c*, Fig. 2283, inclosed within the valve-box *I*, being situated close to its junction with the main steam-valve chest *J*, and brought within the control of the attendant workman by means of the rod and lever *d d*. The alternate admission of the steam into the cylinder by the port *f*, and its escape therefrom by the passage *g* and waste steam-pipe *K*, are regulated by means of the slide-valve *e*, which may either be worked by hand, or, through the intervention of self-acting mechanism, by the action of the machine itself. The piston *L*, which is strongly constructed of malleable iron, is fitted with a single packing-ring, works steam-tight within the cylinder *D*, and is attached by the piston-rod *E* to the hammer-block *F*. Steam acting beneath the piston raises the hammer, and by opening the communication between the under side of the piston and the external atmosphere, the action of gravity causes the hammer to descend upon the work placed on the anvil.

The mode adopted for connecting the piston-rod to the hammer-block consists in placing in a cylindrical recess formed in the body of the hammer-block, and under the knob *i*, on the end of the piston-rod, a series of pieces of hard wood, or other slightly elastic material, as in Fig. 2281. The effect of this arrangement is to allow the momentum of the piston and piston-rod to expend itself in a comparatively gradual manner. The connection of the piston-rod and hammer-block is secured by means of the two keys *k k*, driven very firmly *above* the knob or button *j*, a layer or two of the elastic material being interposed for the purpose of neutralizing any shock in the contrary direction.

We shall now proceed to describe the mechanism by which the height of the fall of the hammer, and consequent intensity of the blow, may be modified according to circumstances, and the machine made perfectly self-acting.

The requisite alternating motion of the steam-valve *e* is produced in the following manner: The valve-spindle *l* is prolonged upward and attached to a small solid piston *m*, working within a short cylinder *M*, bolted to the main steam-cylinder *D*. A small portion of steam is supplied above the piston *m* by a slender copper tube *n*, communicating with the steam-valve chest *J;* by this arrangement it will be seen that, unless counteracted by some superior force, the pressure of the steam upon the piston *m* will tend to keep the valve *e* constantly depressed, in which position the steam-port *f* is full open. This counteracting force is supplied by the action of the hammer itself; for, by means of the tappet *N* (which is bolted to the hammer-block), coming into sliding contact, when the latter is raised, with the small friction-roller *o*, mounted on the end of a bent lever *O O*, the screwed rod *P*, which is jointed to the opposite end of that lever, is depressed, and that motion being communicated to the valve-spindle *l*, through the intervention of the connecting-rod *Q* and valve-lever *R*, the steam-valve *e* is raised, thus cutting off all further ingress of steam under the piston, and almost at the same instant permitting the escape of that which had served to raise the hammer. By this simple contrivance the upward motion of the hammer is made the agent for its own control in that respect. By comparing the relative positions of the parts referred to, as exhibited in Figs. 2279 and 2283, the nature of the motion above described will be at once most fully understood. To obviate the injurious effects of the shock of the tappet *N* against the lever *O*, a connection is provided at *p*, on a similar principle to that formerly described in reference to the connection of the piston-rod and the hammer-block; and in order to restrict the downward travel of the valve to the proper point, a check or *buffer-box S* is provided, consisting of a small cylinder bolted firmly to the framing of the machine, within which a circular nut, screwed on the lower end of the rod *P*, works as a piston, a few leather washers being interposed between the latter and the closed or upper end of the cylinder. From the above description it will be obvious that the lift of the hammer, and consequent intensity of the blows, depends simply upon the position of the lever *O*, in relation to that of the hammer-block when at its lowest point. The rod *P*, which



conveys the action of the lever O to the valve-lever R, is susceptible of rotatory as well as vertical motion. This motion of rotation is imparted to it by means of a handle fixed to a short axis, working in a bracket T bolted to the framing, and actuating a pair of small bevel-wheels $q\,q$. The nut through which the screw works forms the point of attachment between the rod P and the lever O, the connection being effected by means of a short intermediate rod for the sake of insuring parallelism of motion. A pair of small spur-wheels $r\,r$ (through the first of which the rod P works by means of a sunk feather) serve to transmit the angular motion of the rod P to a similar screwed rod U, situated parallel to and at a short distance from the former; the nut of the screw U forms the fulcrum or centre of motion of the lever O, and the pitch of the threads of both screws being equal, though formed in contrary directions to each other, it is obvious that, on turning the handle, the lever O and all its appendages will be simultaneously raised or depressed, and consequently the lift of the hammer regulated to any required extent, and its amount altered with the utmost ease and precision. The pin which forms the centre of motion of the lever O is protected and secured from lateral strains by the cast-iron guides V and W, seen most distinctly in the sectional plan, Fig. 2280.

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A most essential part of the self-acting gear remains yet to be noticed. It is obvious that, were no provision made for the retention of the steam-valve in the position into which it is thrown by the upward motion of the hammer-block, the latter would not be permitted to have its due effect in the accomplishment of its work; for, as soon as it descended so far as to relieve the end of the lever O from contact with the tappet N, the valve would resume the position into which it is constantly solicited by the action of the *steam-spring* at M, and the descent of the blow would be impeded by the return of the steam into the cylinder before the hammer had completed its fall. To obviate this inconvenience, a simple but most effectual contrivance has been applied. Toward the lower extremity of the valve-screw P a shoulder is formed, against which a short lever w, called the *trigger*, is constantly pressed by the spring x, so that when the rod P is depressed by the action of the lever O, it is arrested by the trigger and retained in that position until the blow has been struck. To release the valve-screw from the trigger, and so permit the return of the valve into the position requisite for effecting a fresh stroke, the following mechanism has been adopted: On the front of the hammer-block, Figs. 2279 and 2283, a lever X, called the *latch-lever*, is fitted to work freely on a pin passing through the body of the hammer-block. That portion of the latch-lever which is most remote from the valve-gear is considerably heavier than the opposite end, and is constantly pressed upward by means of a spring. The lighter end is brought into contact with a long bar $s\,s$, called the *parallel bar*, the extremities of which are suspended upon two small bell-cranks $t\,t$, whose other arms are connected by means of a slender rod u, Fig. 2282, forming a species of parallel motion, for the purpose of adapting this gear to come into efficient operation at whatever point in the range of the hammer its blow may be arrested. A small connecting-rod v, between the lower bell-crank and a short lever on the axis of the trigger w, completes this part of the mechanism. The action of this gear is of a very peculiar nature, and is admirably adapted to fulfill the object intended. At the instant the hammer gives a blow to the work upon the anvil, the effect of the concussion is to cause the momentum of the heavy end of the lever X to overcome the upward pressure of the spring, and thereby to protrude its opposite end against the edge of the parallel bar s, which motion, though but slight in amount, is yet adequate, through the arrangements above described, to throw back the trigger from contact with the valve-screw, and leave the latter free to obey the impulse of the steam-spring in the readjustment of the valve into its original position.

The Ferris & Miles Steam-Hammer.—In Fig. 2284 is shown a steam-hammer of modern design, constructed by Messrs. Ferris & Miles. The hammer has a weight of head of 700 lbs. Several peculiarities of design will be noticed, the most striking of them being that the head A is set at an angle in the frame. The die C is of the oblong form shown in the drawing, as well as that of the anvil-die D. The object of this arrangement is to enable the workman, after drawing out his work across the short way of the die, to turn it and finish it lengthwise without being inconvenienced by the

frame. By this means skew and T-shaped dies can be dispensed with, and the full surface of the ram utilized. The latter is moved between the guides *E E*, and held in place by the steel plate *F*, bolted through the frame *B*. The valve *G* is a plain cylinder of cast-iron, enlarged at each end to work in the cylindrical seats *H H*, in which the ports *I I* are placed. Steam is admitted through the valve *J*, and circulates round the valve *G* between the seats. The exhaust-chamber *K* is below the cylinder, which therefore drains condensed steam into it at each stroke through the lower steam-port. The exhaust above the piston passes down through the interior of the valves, as shown by the arrow on the drawing. The valve-stem *L* is connected with the valves in the exhaust-chamber. No stuffing-box is therefore required, there being only atmospheric pressure on each side of it. This combination enables the valve to be so perfectly balanced that it will drop by its own weight while under steam.

The automatic motion is obtained by an inclined plane *M*, upon the ram *A*, which actuates the rocker *N*, the outer arm of which is connected by a link to the valve-stem, and thus gives motion to the valve. The valve is caused to rise in the up-stroke by means of the rocker *N*, and its connections, through the inclined plane. The steam is thus admitted to the top, which drives down the piston, while the valve and connections follow by gravity, thus reducing considerably the friction and wear upon the valves. In very quick work the fall of the valves may be accelerated by the aid of a spring; or it may be retarded in heavy work by friction-springs, so as to obtain a heavier blow by a fuller admission of steam. For general work, however, the arrangement shown is perfectly effective, and as the rocker *N* is hung upon the adjustment lever *P*, any required variation can be obtained by the movement of the lever. Single blows can be struck with any degree of force, or a rapid succession of constant or variable strokes may be given.

The anvil *O* rests upon a separate foundation, in order to reduce the effect of concussion upon the

2285.

frame. Fig. 2284 illustrates the arrangement. The bed is long, extending beyond the hammer on each side so as to give plenty of area, and the ends are left open for convenient access in case the anvil should settle and require readjustment.

The Sellers Steam-Hammer.—In a single-acting steam-hammer the gross force of the blow struck is that due to the weight of the die or hammer, the piston-rod and piston, and the height from which they fall: the force of the blow being regulated by varying the length of the stroke, or, in other

words, the height to which the hammer is lifted by the steam. In many steam-hammers of modern construction the steam is admitted to both sides of the piston, so that the force of the steam upon the upper side acts to increase the force of the blow, the latter being modified by regulating the pressure of the steam above the piston, and for very light blows by throttling the exhaust-steam below it, as well as regulating the stroke of the hammer.

A double upright steam-hammer, by William Sellers & Co., is shown in Fig. 2285. The essential

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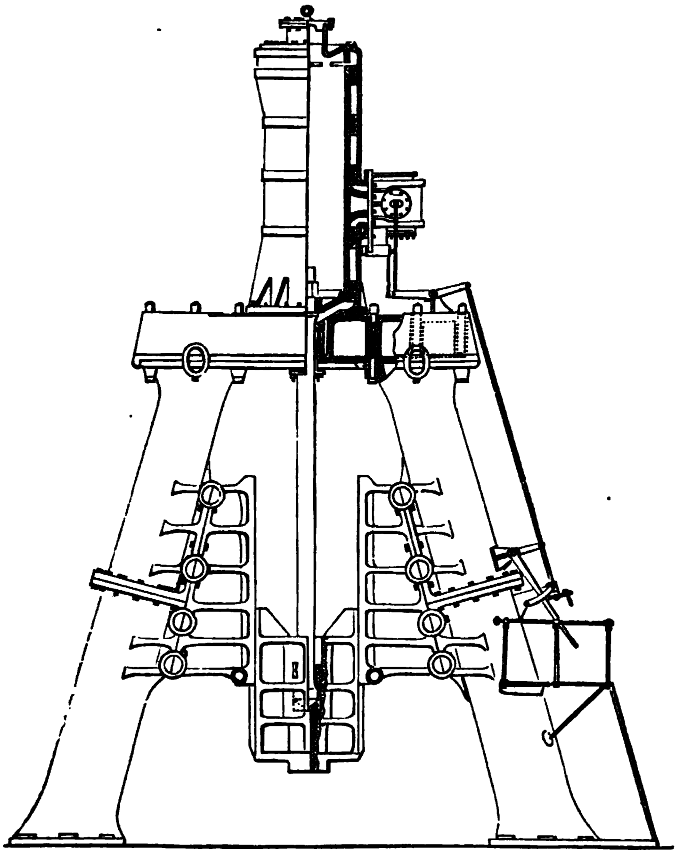


peculiarities in the design of this hammer consist in making the hammer one long bar of wrought-iron, having the piston welded to and forming part thereof, and guiding this bar by the top and bottom cylinder-heads only, thus doing away with the usual side-guides in the hammer-frame, and leaving the entire space below the cylinder free for the use of the workman in handling his work, while the hammer-head and die are claimed to be guided more efficiently than in any other system, and the frames to be subjected to less strain.

An improvement in the manner of attaching the die to the bar consists in employing a crimped steel key, which holds the die with an elastic pressure, and operates to prevent the bending or the fracture of the bar. Another improvement consists in obtaining the motion to work the steam-valve from two diametrically opposite grooves, operating a brass yoke whose line of vibration is through the central axis of the bar, which obviates the tendency to rotate the bar existing when a diagonal groove is employed in the upper end of the bar. By a modification of the ports in the steam-chest enabling the employment of a supplemental valve, the exhaust may be throttled below without impeding the free exhaust above the piston. This enables the hammer to strike quick, light blows for finishing; in other words, the hammer can go up as quickly, but in coming down its force may be gauged by the steam-cushion upon which it descends, which steam, thus condensed in bulk, reëxpands in the up-stroke, to the manifest economy of steam used.

The Thirty-Ton Steam-Hammer.—Fig. 2286 represents a 30-ton steam-hammer, constructed by Messrs. Thwaites & Carbutt, of Bradford, England, for use at the works of Sir William Armstrong & Co. at Elswick. The main standards, it will be seen, are cast of two parts each, firmly bolted together; they are circular in section, taper slightly, and are inclined toward one another. They are 25 feet high, and as they have a clear span at the floor-line of 19 feet 10 inches, there is ample space for the manipulation of the forgings. The guides, which are cast separately, are attached to the standards in a firm, unyielding manner. The entablature on which the cylinder rests at the same

time connects the two standards to which it is bolted and wedged. By this arrangement and subdivision into several parts too ponderous castings are avcided, while at the same time the rigidity of the structure, which must be great in view of the violence and frequency of shocks, is not impaired. The steam-cylinder, permitting a 12-foot stroke, is 4 feet in diameter; it is placed upon the entablature, making the entire height of the hammer 42 feet 9 inches. The piston-rod is very massive and strong; it is firmly keyed to the 30-ton tup, which glides in slots of the guides by means of a projection. An attendant on the platform operates the valves through the agency of rods and levers within his reach. The hammer is, according to Prof. S. Jordan, served by two 20- and two 40-ton cranes, each of which is furnished with three hydraulic motions according to Armstrong's system. The heating is done in four Siemens gas furnaces. The frame, while it is strong, and possesses the advantage of affording ample space, is built up of a reasonable amount of metal. The piston-rod may appear excessively heavy while the tup is proportionately light; this, however, is a distribution of material which has many claims to consideration.

The Creusot Eighty-Ton Steam-Hammer.—The largest steam-hammer in existence (1879) is that constructed by the Messrs. Schneider at the famous factory of Creusot, France, and represented in one of the full-page plates. The largest hammers previously built were the 51-ton hammer at the Perm steel works (Russia), the 50-ton hammer at the Alexandrovski steel works, near St. Petersburg, and the 50-ton hammer at Messrs. Krupp's works at Essen; while after these come the 35-ton hammer at Woolwich Arsenal, and the 30-ton hammer at Sir W. G. Armstrong & Co.'s works at Elswick, England.

In Messrs. Schneiders' large hammer the moving mass weighs 80,000 kilogrammes, or about 78¾ English tons, while the maximum fall is 5 metres, or about 16 feet 5 inches. The hammer is single-acting, and is worked with steam at 70 lbs. pressure, while the diameter of the steam-cylinder is 74.8 inches. The other principal dimensions are as follows:

	Feet.	In.		Feet.	In.
Diameter of piston-rod	1	2.2	Width of bed-plate	19	8.2
Diameter of steam-admission valve (Cornish)	1	1.4	Height of standards	33	7.5
Diameter of exhaust-valve (Cornish)	1	6.1	Length of cylinder	19	8.2
Width of tup between guides	6	2.8	Total height from bottom of base-plate to top of cylinder	61	0
Width between legs of hammer-frame	24	7.3	Height of anvil-block	18	4.5
Clear height under lower cross-stay of framing	10	6	Depth of masonry below anvil-block	13	1.5
Length of bed-plate	41	4	Surface of base of anvil-block	355 sq.ft.	
			Surface of top of anvil-block	75 "	

The framing of the hammer consists of a pair of inclined legs of rectangular box-section, having the guides for the tup bolted to their inner sides, these legs being connected at two points (namely, at the top and bottom of the guides) by massive wrought-iron plate cross-stays, while at the top they are bolted to a deep casting which forms the base of the cylinder. Each leg is cast in two pieces bolted together by external flanges. The cylinder is also made in two pieces bolted together at the middle of its length. Each leg of the frame is forked at its lower end, so as not only to give greater stability, but also to afford access to the anvil from the sides.

In constructing the anvil-block for the large hammer, Messrs. Schneider wisely departed from the practice of making the block in one enormous casting. Instead of this, they made the block in six layers, each (except the top one, which is in a single piece) consisting of two castings. The layers increase in thickness as they diminish in area from the base upward, and the castings composing them are so shaped that each layer is firmly interlocked with those above and below it, the line of division of the two parts of one layer being at right angles to the division line in the next layer above, and so on. The anvil-block rests upon layers of oak timber making up a thickness of about 3 feet, this timber again resting on a bed of masonry in cement over 13 feet thick, which bears directly on the rock below. This bed of masonry extends not only under the anvil-block, but under the whole area occupied by the hammer, it being carried up around the anvil-block to support the hammer itself, and the space between the masonry and the anvil-block being packed with oak timber. It follows from the mode of construction adopted that in the event of anything going wrong with these foundations, it would be quite possible to lift the anvil-block piece by piece, and to make the damage good; whereas, if the block had been cast in one piece, any settlement, if it did take place, would be very difficult to deal with.

The weights of the various parts of the hammer are as follows:

	Tons.
Tup with piston and rod	80
Cylinder	22
Entablature	30
Legs of hammer-frame with guides	250
Wrought-iron cross-stays	25
Foundation-plate	90
Valves, valve-gear, and miscellaneous	35
Total weight of structure above ground	532
Anvil and anvil-block	750
Total	1,282

To serve this magnificent hammer, four cranes have been erected, three of them being capable of lifting 100 tons each, while the fourth can deal with a load of 160 tons. They are all of the revolv-

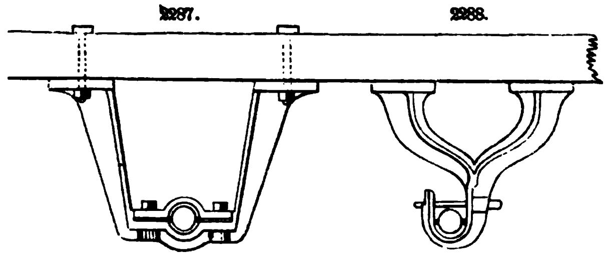
THE SCHNEIDER EIGHTY-TON STEAM-HAMMER.

ing post class, with jibs formed of curved box-girders, the part of each crane below the ground line being also a box-girder of rectangular section tapering from the ground level to the bottom. The weight of each crane with its load is carried by a ring of live rollers at the ground level, the bottom of the crane-post having a gudgeon taking lateral stress only. The foundation-plates of the cranes are connected to the foundation-plate of the hammer as well as to the masonry, and the whole work has been carried out so as to make a thoroughly sound job. Each crane has a maximum radius of 30 feet 8 inches, the chain carrying the ingots passing over pulleys on a traveling carriage, which can be racked in and out on rails on the top of the jib. The height from the floor level to the top of these rails is 29 feet 6 inches, while from the floor level to the bottom pivot is 27 feet 6 inches. The total weight of each 100-ton crane is 110 tons, while the 160-ton crane weighs 140 tons. Each crane is actuated by a steam-engine fixed to it, this engine having a pair of cylinders 10.24 inches in diameter with 11.8 inches stroke, the speed at which these engines are run being 250 revolutions per minute. The engines work not only the lifting, swinging, and racking in and out motions, but also serve to turn over the forging which is under manipulation. This operation is effected as follows: The forging rests as usual in a loop or bridle of massive chain, this loop passing over a pulley mounted on a frame to which the crane-chain is attached. This frame also carries worm-gear through which, and an intermediate wheel and pinion, the pulley carrying the bridle-chain can be rotated. The worm of this gear is coupled by a shaft with two universal joints to a short shaft on the crane-frame, and this shaft again by a vertical shaft and bevel-gear is connected to the crank-shaft of the engine. The use of the connecting-shaft with two universal joints of course allows the forging to be raised and lowered without interfering with the connection between the engine and the bridle-gear.

The furnaces used in connection with the 80-ton hammer are four in number, and they are of the Siemens regenerative type. The heating chamber of each furnace is 14 feet 1 inch long by 11 feet 2 inches wide, and 8 feet 6 inches high in the centre, the crown being arched in both directions. The doors of these mammoth furnaces are raised and lowered by chains led down to horizontal hydraulic cylinders disposed below the floor-line. In each of these furnaces the regenerators are as usual below the bed, the regenerators of each furnace being built in a circular pit, which also contains the hydraulic gear just mentioned, and the reversing valves for gas and air. The part of this pit in front of the furnace is bridged over by massive wrought-iron girders carrying rails, in which a charge can be run to or from the latter. The furnaces are supplied with gas from four groups of nine generators each, which also furnish gas to the other Siemens furnaces in this department. The 80-ton hammer with its accessories is contained in a building of which the frame is solely of iron. This building is 164 feet long by 114 feet 9 inches wide, and 55 feet 9 inches high to the springing of the roof. To the ridge of the roof the height is 83 feet 8 inches, and to the top of the lantern which the roof carries 92 feet 7 inches. The building is spanned by girders carrying two 20-ton crabs, which serve for handling parts of the hammer for repairs, etc. (See *Engineering*, xxvi., 28; also *Annales Industrielles*, 1878.)

HANGER. A device for supporting shafting from overhead or from the side. When old-fashioned large couplings were used to connect shafting, hangers of the forms shown in Figs. 2287 and 2288 were used. The modern adjustable coupling obviates the necessity of spreading the hanger-legs apart, and admits of the weight of the appliance being materially decreased. The bearings shown in these figures are also disadvantageous and practically obsolete. That exhibited in Fig. 2287 has brass bushings held in place by an iron cap secured by bolts. In Fig. 2288 the cap is dispensed with, and the top brass is fastened only by a pin.

2287. 2288.



For very heavy head-shafts, the ordinary forms of hanger are not sufficiently rigid to stand the lateral strain of the driving-belts, and it is therefore generally the custom to use inverted pillow-blocks bolted to enough timbers to bring the distance of the drop equal to that of the rest of the line. This has the advantage that the head-shaft and its pulleys may be hoisted directly into place and secured, but has the disadvantage that it is impossible to remove the top box for any purpose without supporting the shaft by ropes or blocking or in some such way. It is open to the further objection that it possesses no vertical adjustment. To obviate these defects, Messrs. William Sellers & Co. have designed a special *head-shaft hanger*, Fig. 2289. The cap, supported by T-head bolts, is removable like that of a pillow-block; but as the box is supported by screw-plungers, it not only has a vertical adjustment, but like a hanger will permit the top box to be removed without altering the alignment.

Fig. 2290 represents a sectional view of a *ball-and-socket hanger*. The two half boxes *b* and *c* are provided with turned spherical surfaces, which fit into corresponding concave surfaces in two plungers *d* and *e*. These plungers work with a coarse thread in two boxes *a a*, in the frame of the hanger, and are secured from turning by two set-screws. The plungers offer a vertical adjustment, while the ball and socket enable the boxes to adjust themselves to the shaft. The top box has oil-holes in the centre and sides of the ball, and oil may be fed from an oiler placed on the top plunger *d*. Two recesses, covered by loose cast-iron caps, are also provided to contain a mixture of oil and tallow that will act as a reserve to be used if the box should begin to heat; while an oil-dish or drip-pan *f* catches the oil that drips from the ends of the boxes, which are provided with suitable internal

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grooves to distribute the oil. The vertical adjustment afforded by this style of bearings is one of their most important qualities, and one that cheapens the erection of shafting and facilitates its realignment. It becomes necessary only to put up the hangers with the centres of the boxes in the same vertical plane, and any adjustment up or down in that plane may be readily accomplished by the plungers.

Ball-and-socket bearings are made of different bores to suit the commercial sizes of shafts, and of various forms to suit different circumstances. Thus we have *line-hangers*, Fig. 2291, which are of various "drops" or distances from the foot (under side of beam) to the centre of the box, ordinarily from 8 to 30 or 36 inches. In ordering, it is customary to mention both diameter of shaft and drop; as, "a 2-inch hanger, 10-inch drop," or "a 3-inch hanger, 16 inch drop."

For countershafts, hangers are made with ball-and-socket boxes, but without vertical adjustment, such as those in Figs. 2292 and 2293, both with and without an arm to carry a belt-shifting bar. For attachments to posts or walls, post-hangers, Fig. 2294, are made. These are often provided with concave feet to fit cast-iron columns of different diameters. C. S., Jr.

HARDENING. See Tempering and Hardening of Metals.

HARNESS. See Looms.

HARROW. See Agricultural Machinery.

HARVESTER. See Agricultural Machinery.

HAT-MAKING MACHINERY. The manufacture of felt hats in the United States has gradually become divided into two independent branches—the production of fur hats, made from the fur of the gray or white rabbit or hare, known in the trade as cony or Russian fur, and of wool hats, made from different kinds of wool. Very few hats are manufactured from a mixture of fur and wool, or with bodies of wool covered with fur. Although the methods of making fur and wool hats are apparently similar, yet the machinery employed differs so materially that both branches of the trade are rarely conducted in the same establishment.

Manufacture of Fur Hats.

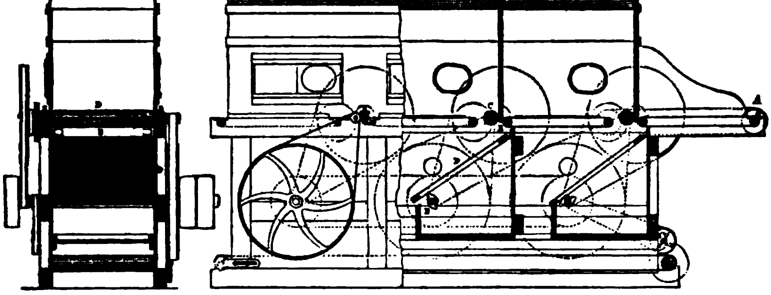
There are various ways of preparing fur for felting. Hare-skins are split open and rubbed with a rough knife-blade to remove bits of adherent fleshy matter. They are afterward dampened on the pelt side and pressed together pelt to pelt. Rabbit-skins are treated in a similar manner, except that the long hairs are pulled instead of being clipped. They are thus made ready for cutting.

Cutting is accomplished in a machine having a rapidly-revolving cylinder, in the periphery of which three or more knives are obliquely set, and which rotates in close proximity to a stationary bed knife. The skin, resting upon the bed-knife, is divided into narrow strips, and is then cut away from the pelt, which is thus left in a continuous sheet. The fur is carried by an endless apron to a workman, who separates it into various grades and packs it in bundles.

Beaver and nutria skins require more care in their handling than do rabbit or hare skins. They are loaded with fat, which must be removed by soap and water, and they are subsequently treated with a dilute solution of nitric acid. This process also assists the felting properties. Skins that have been thus treated are said to be "carroted." Thorough drying should follow. Hair is sometimes prepared in a solution of quicksilver and urine. All furs are more or less mixed with long hair, and for the removal of this the fur-blowing machine is employed.

The Fur-blowing Machine is represented in Fig. 2295. The material is spread upon a feeding apron *A*, and by means of two rollers *B* is presented to a rapidly-rotating toothed cylinder *C*. The motion of this cylinder creates an air-current, which carries the lighter particles of the fur upward

2295.



into a chamber which is closed by a fine wire screen, through which the air escapes, carrying the finer particles of dust with it. The hair and coarse particles fall upon a wire screen, which is vibrated by a cam *E*, and thence pass upon an apron, which delivers them under the feed-apron. Another feed-apron forms the bottom of the chamber into which the fur passes; and as the fur settles on this apron it is conducted to a second pair of feed-rollers, which carry it to another picker-cylinder, where the operation already described is repeated.

Most fur-blowing machines contain from 5 to 8 picker-cylinders, the fur being delivered in an endless sliver to the last pair of rollers. Hair and impurities which pass through the screen are collected. Fur which does not pass through is carried back by an apron and subjected again to the action of the machine. This operation is continued until the quantity of hair is reduced as much as

is possible. In forming the hat-body various kinds of fur are mixed in an apparatus which contains a picker-cylinder, whereby the fur is loosened and thrown into a closed room, or into a machine similar to that above described, by which it is delivered in a continuous bat. The fur thus prepared is weighed and separated into portions, each of which is sufficient to form one hat-body.

The Forming Machine.—The apparatus generally in use is that invented by H. A. Wells in 1846, and since greatly modified and improved by Taylor, Burr, and others. In the Wells machine the fur is conducted to a forming cone by an adjustable trunk, while in other machines, such as that devised by Gill and Taylor, it is thrown into a case which surrounds the former-cone, and is conducted to the cone by an air-blast from a blower beneath. Fig. 2296 represents a Wells machine of late construction. An apron and two small feed-rollers deliver the fur to a rotating picker-cylinder. The air-current caused by the latter carries the fur to the mouth of the trunk. The size of the aperture is adjustable to correspond to that of the cone used. The cone is made of perforated sheet-copper, and is placed upon a revolving table, in the centre of which is an opening communicating with an exhaust-fan, by means of which an air-current is drawn in through the perforations, so that the fur is thus caused to be deposited over the surface of the cone. This process continues until all the fur set apart for one hat-body is thus deposited. Over the material a wet cloth is wrapped, and over this again a tin cover is placed, when the whole is removed and dipped in hot water in order to give the felt a sufficient consistence to allow it to be removed from the cone.

Hardening the felt, which follows, is done by placing six or more of the felt-cones formed as above one upon the other, wrapping them in a wet blanket, and rolling them back and forth by hand on a smooth board.

Sizing.—This name is given to the manipulations by which the felt is reduced to the proper size for hat-making. Up to a very recent date (1879) this work was done, and is still largely performed, entirely by hand. Three or four hat-bodies are dipped into boiling water (sometimes slightly acidulated), and then are wrapped in cloths, making a bundle some 4 inches in diameter. The bundle is rolled to and fro on an inclined plank, and the pressure of the hands is carefully graduated to the consistence of the hat-body. After being rolled for a short time, the bodies are separated and placed together again in different position, so as to prevent their sticking together. As the process continues, the roll is made tighter and the pressure increased, until the body has attained the desired size. The felt is then "pinned out"—that is, smoothed and tightened by pressure with a rolling-pin and frequent dipping in hot water.

The machines used for this purpose are the invention of Mr. R. Eickemeyer of Yonkers, N. Y., and are modifications of the fulling-mills used in the manufacture of wool hats. The bodies after leaving the former are placed first in pusher-crank mills. These mills have a single pendulum-beater suspended from the top of an iron frame and operated by a bell-crank, which receives motion from a crank on the main shaft. The wrist-pin on the bell-crank is adjustable, so that the force with which the bodies are pushed against the curved part of the bed may be graduated. This operation is continued until the felting has progressed far enough to allow the hats to be placed in the fulling-mill proper, Fig. 2297. This machine has a single beater pivoted to the front of the frame. On the opposite end is a horizontal driving-shaft, which makes 120 revolutions per minute. In the middle is a gripping-roller, against which a lifting board attached to the end of the beater-handles is at regular intervals pressed by another gripping-roller journaled in a swinging frame. A stepped pulley on the driving-shaft communicates motion to a second shaft, on which are cams which actuate the swinging frame. The speed of this shaft determines the period of lift and drop of the beater. The amount of lift and drop can be regulated from 50 lifts 8 inches high per minute to 38 lifts 20 inches high per minute. The fulling-bed is formed of two pieces of metal hinged at the base, the lower portion being perforated to allow entrance of steam during the fulling process. The front portion is hinged to the stationary part, and is connected by links to a rock-shaft and lever which enables the operator to increase resistance to the movement of the hat-bodies. When the mill is first set in operation, the beater is adjusted to a fall of about 8 inches, and is run at the rate of 50 blows per minute, care being taken that the position of the hats is constantly changed. As the fulling progresses the front is lowered, and the fall of the beater increased and its rapidity reduced, until at the end the fall becomes fully 20 inches a. d the blows 38 per minute.

After being fulled, the hat-bodies are passed while hot through a pinning-out machine, Fig. 2298, in order to tighten the felt and smooth them. This apparatus consists of two pairs of rollers, one pair having rigid bearings, the other being pivoted in weighted levers. The upper pair of rollers is slightly the larger in diameter, and all revolve at the same uniform speed. Through these the body, after being dipped in hot water, is passed. The diameter of the lower rollers being less, however, than that of the upper ones, the hat-body is drawn out between them, and the felt at the same time is rendered compact and free from wrinkles.

Sizing Machines.—Numerous attempts have been made to construct sizing machines to supplant the hand-sizing process. The machines operate upon a limited number of hats, rolled in a cloth and kept in motion by rollers which have a vibrating movement. In one class of machines these rollers are irregularly ribbed to press successively upon different parts of the hat. The machine devised by Mr. J. S. Taylor of Danbury, Conn., in 1853, has four rollers, so journaled in their frames that their axes are inclined to the centre of the hat-roll, and one pair of rollers has a vibrating motion in addition to its movement of rotation. In the machine devised by Mr. J. W. Blackham of Brooklyn, N. Y., a number of slowly-revolving rollers form a bed over which is placed a yielding cover, having a vibrating motion in a direction at right angles to the axes of the rollers. The hat-rolls are passed between cover and bed several times. It has not been found profitable to begin sizing the body by machinery as soon as it leaves the former, and hence the present practice is to size the body by hand until it is within an inch of its desired dimensions, and then to complete the work in the sizing machine —or, as it is then termed, the second-sizing machine.

2298.

A machine adapted to this second sizing has been devised by Mr. J. Vero of Dewsbury, England, and improved by Kirk, Shelmerdine, and Froygate, of Stockport, England. The improved apparatus has four rollers driven all in the same direction by gearing. The lower pair of rollers is journaled in the stationary frame, while the upper pair is journaled in a swinging frame, which can be lifted up whenever the hat-roll is to be inserted or removed. The working surface of the rollers is formed of elliptical rings, made of India-rubber, and placed so as to overlap each other. Generally, two rolls of hats are kept in operation, one roll being acted upon while the positions of the hats in the other are being changed.

Fig. 2299 represents a machine of this class. Two beaters act upon the ends of the hat-roll. Four cubical pressers are provided, so arranged that the hat-roll is pressed at each quarter revolution of the pressers. These are journaled upon two swinging frames, which are so connected by links to

levers in the rock-shaft that, while balancing each other, the pressers can be separated to take out or insert a hat-roll, or be brought together by a weight on the hand-lever. The pressers are actuated from the main shaft, two cams on which operate the beaters. On each beater is a projection, to which an adjustable spring is attached in order to graduate the blow upon the hat-rim. Devices are provided whereby the spring may be held at any tension suitable to the condition of the bodies. By a gradual increase of the weight which presses the rollers or pressers together, and a similar increase of the tension of the beater-spring, the action of the machine is adjusted as the felting progresses.

Some grades of hats are sheared before the sizing or felting is finished, in order to remove long hairs. Eickemeyer's machine for shaving hats is represented in Fig. 2300. The hat is placed on a padded board of the same shape as the body, and a knife is caused to vibrate rapidly over the surface of the latter while the feeding mechanism draws the hat along, slowly rotating it. The best speed of the knife is from 600 to 650 strokes per minute, and from 3 to 6 dozen hats can be shaved without change of knife.

2300.

Stiffening the hat-body is the next process. After drying, the felt is dipped in an alkaline solution or one of shellac. Stronger solutions are used for the brim than for the crown of the hat. Passing between weighted rollers follows, the surplus stiffening material falling back into the tank to which the rollers are attached. The body is folded and rolled several times, until the stiffening solution is evenly distributed. The brim is stiffened afterward, and rolled in similar manner. Some manufacturers prefer to apply all the stiffening after the body has been blocked and colored; while others only partially apply stiffening in advance, reserving the completion of the process until after blocking. After stiffening, the body is steamed, and is then ready for the initial shaping processes.

Stretching and Blocking.—The hat-body has now reached a point where it begins to assume a semblance of the completed article through the development of the tip, side-crown, and brim. Many attempts have been made to accomplish shaping by machinery. The first United States patent was granted to Mr. D. Beard of Guilford, N. C., in 1816, for a machine for stretching hat-crowns. Other devices have subsequently been invented and come into limited use; but it appears that the practical difficulties were not successfully overcome until the invention in 1865 of the hat-stretching machines of Mr. R. Eickemeyer. In previous apparatus the effort was to stretch the hat-body from the centre; in the Eickemeyer machines the body is stretched over a ribbed and recessed former,

and is thus drawn out radially, the centre being widened at those parts which form the crown and brim of the hat. The *former* is secured to a sliding spindle, which is actuated by a treadle and link. Directly over and in line with the spindle are suspended adjustable stretching-fingers. When these are brought down by means of a hand-wheel connected with their spindle, they are closed in around the hat-body, and their pressure is increased. To suit hats of varying diameters, a star is fastened upon the spindle. The hats to be stretched are first soaked to render the felt pliable, then placed upon the star, and forced down upon the stretching-fingers. This operation is repeated five or six times. At each motion the height to which the body is lifted and turned, to bring the stretcher in contact with all parts, is increased. Usually two hat-bodies are stretched at a time, both being turned inside out so as to protect them against injury through contact with the stretching-fingers.

The brim-stretcher is represented in Fig. 2301. This consists of a series of expansible ribs mounted upon a sliding spindle in the centre of the machine. Connected with the spindle is a system of links and levers operated by the treadle, by which means the spindle is caused to rise, and so bring the ribs into working position. Above the ribs is a hat-block which can be adjusted to any height. The stretching-fingers are so arranged as to be automatically reciprocated toward or from the centre of the machine. The outer ends of the fingers are connected by short links to a ring fastened to two upright sliding bars, which have their bearings in the side frames of the machine, and receive motion from the crank on the main shaft. The crank-shaft makes from 300 to 350 revolutions per minute, producing the same number of vibrations of the stretching-fingers. The hat-body is adjusted upon the block, the treadle is depressed to its full extent, and the hand-lever on the right of the machine is raised. The ribs upon which rests that portion of the body which is to form the brim are spread out between the vibrating fingers. After 10 or 15 stretches are made by the fingers, the block is lowered sufficiently to turn the hat upon it, so as to bring the fingers upon that portion which previously rested on the ribs, and the operation is repeated. From 30 to 40 vibrations of the fingers are usually sufficient to stretch the brim to its full extent.

These machines differ considerably in construction, according as they are applied to different uses. Fig. 2302 represents the Eickemeyer fur-tip stretcher. In this the fingers are mounted on a spindle which has its bearing in line with the sliding spindle which supports the star. To this spindle a short walking-beam, which also communicates with the crank-shaft, is hinged. Each revolution of the main shaft thus causes vertical movement of the spindle, and also of the stretching-fingers. In practice the best results are obtained at from 100 to 150 revolutions of the main shaft.

2806.

Blocking.—Fig. 2806 represents the Eickemeyer hand hat-blocking machine, which operates as follows: A hat previously stretched on the tip, side-crown, and brim is clamped on the outer edge and expanded to the desired size. Thirty-six clamping tongs are pivoted to the top plate, in an oval line around the block, and these are attached to the foot-lever so as to move outward from the centre when the lever is depressed. Each one of the clamping-tongs is also connected to a clamping-lever, so that all may be simultaneously drawn upon the brim placed between them. An adjustable block composed of 48 pieces, which are also spread out from the centre by one of the levers shown, is mounted on a sliding spindle, and can be raised or lowered. To form the band of the hat, a ring of the exact size and shape is suspended from the hand-lever which is pivoted horizontally to brackets. Adjusting-screws are provided for regulating the height and diameter of the crown, and "brim-tongs" govern the exact width to which the brim is to be drawn out.

The operation of blocking is performed as follows: The upper or banding lever having been raised, the block is contracted and lowered, and the clamping-tongs are closed in. One or two hats, having been thoroughly heated in hot water, are placed upon the block, the brim resting upon the heads of the clamping-tongs, which are now expanded sufficiently to allow the edge of the brim to slip down upon the lower jaws. The tongs are then made to approach the hat until the edge of the brim touches the upper jaws all around, when the clamping-lever is pulled forward, and all the upper jaws are closed upon the brim, which is thus firmly held and slowly expanded to full size. The hat-block is in the mean time raised and the banding-lever lowered; and after the block has been expanded, the workman gives the banding-lever rapid up-and-down motion to form the band. The hat is then cooled in place by cold water, when it sets in proper shape. From 50 to 80 dozen hats can be thus blocked per day. The hats are next washed and colored, and usually blocked a second time. They are then ready for the pouncing machine.

Pouncing Machines.—Various forms of these machines are used. In one of the simplest the hat is subjected to the scraping action of a rapidly revolving cutting-cylinder. In another, the abrading material is sand- or emery-paper secured to vibrating arms. In a third, the hat is fastened to a block which turns to and fro around its centre, while the rubbing material is held up to its surface. The first-mentioned machine is best adapted for coarser grades of hats, the others being preferable for hats of fine quality. Fig. 2304 represents the Universal pouncing machine, by means of which a hat-body which has not been blocked is pounced. A conical roller covered with fine sand- or emery-paper is secured to a horizontal shaft, and makes from 2,000 to 2,500 revolutions per minute. Conical feed-rollers, one of which in Fig. 2304 is shown as pressing upon the hat-body while the other is in the inside of the latter, have their bearings in two frames hinged to the main frame. These may be adjusted nearer to or farther from the cutting-roller, as well as longitudinally in the direction of the axis of the cutting-roller shaft, so that hats of any shape may be operated upon. The relative positions of the feed-rollers may also be varied so as to press harder at any desired point. The hat is supported on a horn hinged to the main frame, and is kept in working contact by the attendant pressing upon the treadle shown. A small exhaust-blower serves to remove the material abraded or cut off. The machine just described is chiefly used for pouncing brims, the side-crown and tip of the hat being operated upon in another apparatus

2305

Fig. 2305 represents the Labiaux crown-pouncing machine. Two spindles are provided, one of which has a hat-block secured on its inner end, while to the other the cutting-cylinder is fastened. These have their bearings in lathe-heads mounted centrally upon and pivoted to short columns, which can be turned around by suitable handles. Both spindles slide longitudinally in their bearings, and in the flanged pulleys which give motion to them. A fast motion is given to the cutting-spindle, and a comparatively slow one to that which carries the block. After the hat has been tightly drawn upon the block, the machine is set in motion, and the spindle of the block is turned on its column until the tip of the hat touches the cutting-roller; the block is then turned slowly back while the cutting-roller is pressed against the surface of the hat, and is slowly passed over the square side-crown and tip, often two or three times to produce the necessary smooth finish. This machine is in some establishments used only for rough work, fine pouncing being completed on the apparatus illustrated in Fig. 2306, and known as the Rosekranz brim-machine.

2306.

In this device two vibrating rubbing arms are pivoted to a heavy frame, and actuated in opposite directions from an upright crank-shaft. Each arm has on its outer end a plate covered with sand- or emery-paper. The upper arm is attached to the treadle on the right of the machine, and can be

raised to introduce or remove the brim of the hat. A swinging frame contains the shafts of the two conical feed-rollers, the upper one of which is raised when desired by the treadle, otherwise the weight shown presses it upon the hat. The rollers receive motion from the upright shaft in front of the machine, through a system of bevel-gear. To regulate the motion of the hat circumferentially, the rollers can be set close to the rubbing plates, or for wide brims they may be moved farther away. Means are provided for holding the treadle down, and thus keeping the rubbing surfaces and feed-rollers apart, when the machine is in motion but doing no work. The feed-rollers, first grasping the brim, give it a slowly rotating motion, and the rubbing plates when closed act against both sides of it. This produces a smooth and even surface.

2307.

To pounce the crown, it is necessary to place the hat over a block. A machine for crown-pouncing is represented in Fig. 2307. An upright spindle, which has its bearing in the frame, communicates with the sliding head by two straps which are fastened to opposite ends of a cross-head, and also are wrapped in opposite directions around the spindle, and are attached one near the upper, the other near the lower bearing of the latter. The cross-head is connected by rods to the wrist-pin on the fly-wheel The motion imparted to the cross-head through the connecting-rod is transmitted through the two straps to the spindle, and produces two revolutions of the latter, first in one and then in the other direction, to each turn of the driving-shaft. The block for the reception of the hat is secured upon the upper end of the spindle, and may be removed by means of the small hand-lever shown. The rubbing material is held against the crown by hand, and is slowly carried all over the surface.

2309.

2308.

Finishing Hats.—The finishing of fur hats includes the final blocking, the shaping, ironing, and smoothing. Soft hats are first drawn over a block of the desired shape. The brim is then flattened out, and while damp the hat is ironed all over. Rubbing with fine sand-paper follows, and then several repetitions of the wetting and ironing for fine goods, or only two ironings and wettings for inferior grades. To give the hat a velvet finish, it is ironed first, then carefully rubbed over with fine sand- or emery-paper, and finally held over a jet of steam which raises the nap. It is afterward singed.

Stiff hats are differently treated. The hat is first steamed on a block, the brim flattened, and the surface rubbed with emery-paper. The brim is then cut to the right width, and the binding is put on. The brim is next to be curled, and for this purpose it is placed upon a convex plate heated by steam. This softens the brim, so that it can be turned over toward the crown and ironed down, forming a fold or roll gradually widening from the front and rear to the sides. The brim is then bent to any shape or curve, according to the prevailing fashion. To shape a stiff felt hat properly is the most difficult part of its manufacture.

Hydraulic presses have of late been used with some success in pressing stiff hats. The hat is heated in an oven by steam, and is pressed either in a cold mould or in a hot one, to shape the crown and flatten the brim. In one machine of this kind, the hat is placed in a mould and an India-rubber cover is closed over it. This cover or diaphragm is expanded and pressed against the hat by water forced between the diaphragm and a stationary head by a pump. A press manufactured by Mr. George Yule of Newark, N. J., is represented in Fig. 2308. It consists of a heating chamber in which the hat is placed upon its block. The press-follower is driven down by the piston of the hydraulic cylinder, and is balanced by the counterweight shown. A pressure of about 300 lbs. is usually applied.

Ironing Machines.—Fig. 2309 represents an improved ironing machine which operates upon all parts of the hat. Its action is entirely automatic, one operator being able to attend to two or more machines. The chief improvements embodied consist in the attachment of side-crown and tip irons to a vibrating arm, to enable the latter to iron the square of the hat, and the introduction of a fast-running ironing disk to iron the under brim. The hat, secured on the finishing block, is placed on an upright shaft which revolves slowly. Another upright spindle, situated about 10 inches to the right of the first, has a disk fastened to its upper end, which is heated by a Bunsen gas-burner. This disk revolves about four times as fast as the hat-block, and in the opposite direction. Its flat side, which acts as an iron for the under brim, is adjusted level with the under side of the hat. A traversing motion is imparted to the tip and side-crown irons, so that they move from the centre of the tip and side-crown to the square of the hat. The device for ironing the upper brim is suspended in a hinged lever, and is held by a weight up to the hat-block. In operation, the upper brim-iron is placed upon the brim; and as the friction of the latter on the iron has a tendency to draw the brim along, while the fixed upper iron retards this motion to the same extent, no wrinkling of the material is produced. The tip and side-crown irons are arranged to follow the irregular shape of the block. The traverse motion is then started, and the irons move to and fro, thus completing the smoothing of all parts of the hat.

2311.

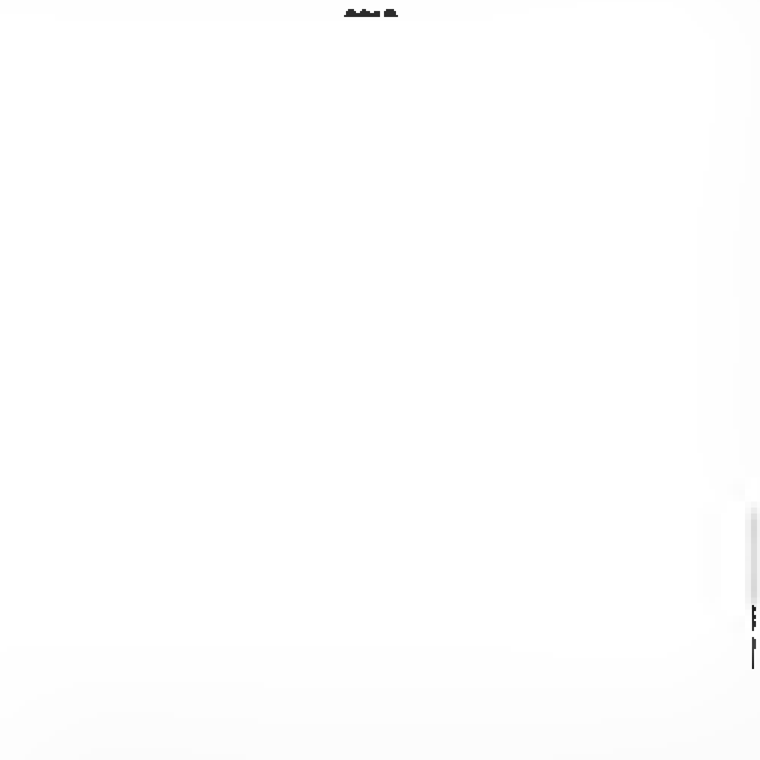
When sufficiently ironed, the hat is placed in a pouncing machine, Fig. 2310, on a block which is mounted on an eccentric chuck, which has a reciprocating as well as a rotary motion. Rubbing with sand- or emery-paper follows, and then another ironing; and finally, if a velvet finish is desired, the hat is singed.

MANUFACTURE OF WOOL HATS.

The machinery used for preparing wool for hat-making is the same as that employed in its preparation for spinning. (See WOOL MACHINERY.) The former used for making the hat-bodies is

placed in front of the carding machine, and the sliver is wound upon a double cone, making two hat-bodies at a time. These are divided and removed from the cone when a sufficient quantity of material has been gathered. The wool-former is older than the fur-former, and it remains substantially as it was patented by Mr. J. Grant in 1827, all modifications tending to make its parts more adjustable and to increase their durability. The machine is represented in Fig. 2311. It is constructed so as to be easily adjustable to suit the largest size of man's or the smallest size of child's hat. Arrangements are provided whereby an equal quantity of wool is wound on both sides of the former-cone. The speed of the latter is regulated by shifting a small spur-wheel on the countershaft, which has its bearing in a swinging frame on the side, and is parallel with a series of gear-wheels of varying diameters keyed upon the main driving-shaft. Another improvement is the arrangement of a stop-motion to arrest the movement when the former-cone is parallel with the carding machine. When a large quantity of wool is to be wound on the cone to form a heavy brim, it is necessary that the machine should stop in proper position, and this is effected by the automatic devices provided.

2311



Hardening.—Fig. 2312 represents a double hardening machine. A board of the shape of a hat-body when flattened out is connected with an adjustable wrist-pin on the fly-wheel. Steam-boxes of the shape of the body are set in the top of the table, and are perforated for the passage of steam. A piece of cloth is inserted in the body to separate the sides, and several bodies thus prepared are superposed. The engraving shows one of the boards resting upon two hat-bodies and held down by a post, which presses it upon the bodies with sufficient force to compress them to a thickness of about a quarter of an inch. The rapid vibration of the hardening board upon the hats renders the material sufficiently tough to stand the action of the fulling-mill. After one side has thus been hardened, the bodies are removed and refolded, and the operation is repeated.

Fulling.—The first operation of fulling is conducted in a crank-mill essentially similar to that described as for fur hats, but which has two beaters acting in opposite directions on one fulling-bed. The hats are here fulled with fullers' soap. Afterward they are placed in the mill represented in Fig. 2313. Four cast-iron frames fastened upon a solid foundation support the shafts upon which the hammers are pivoted, and also the fulling-bed, which is divided into two compartments. The hammers are lifted by toes on the two large gear-wheels, one of which is shown in the engraving. The capacity of these mills is from 20 to 25 dozen hats fulled in from 24 to 48 hours. The hammers are lifted in succession and drop upon the goods, which are slowly turned. In some cases steam is admitted into the mill. After fulling, the bodies are washed in a crank-mill, and are then ready to be stretched and blocked, or stiffened and then stretched and blocked, as the goods may require.

2313

Stretching and Blocking.—The Eickemeyer tip-stretcher, already described under fur hat manufacture, is largely used for this purpose. A special machine has however been devised, which is illustrated in Fig. 2314. This apparatus has a former of peculiar shape. The ribs which support the tip are connected, and the stretching-fingers are formed at an obtuse angle on the line where they come in contact with the body. Each finger is hinged at its middle to a disk, which is attached to the upright cylinder fitted in the upper cross-piece; and on its outer end it is secured to a ring which is held by set-screws to the two sliding rods in the side frame. The ring is actuated through connecting-rods by the crank-shaft, and thus caused to make an up-and-down movement at each revolution of the latter. The walking-beam on top of the machine is attached on its left end by a link to the cross-piece, at its middle to the cross-piece which carries the sliding fingers, and at its right-hand end to the vibrating ring. This connection gives to the disk an up-and-down travel of

2314.

about half the length of that of the ring. The fingers, as already stated, being hinged to the disk and ring, thus have at their lower extremities a movement to and from the centre of the hat, while they remain stationary at their point of meeting above. The effect of this is that the hat-tip is stretched peripherically only, and not radially in addition, as is done on some other machines. Each one of the vibrating fingers works in a recess, into which a portion of the felt is drawn at each vibration; and as the body is supported all around, a portion of the crown as well as the tip is drawn out. From 100 to 120 dozen hats per day can be stretched on this machine.

From the tip-stretcher, the hat-body is taken to the power brim-stretcher, and then while hot is placed on the blocking machine. This apparatus, represented in Fig. 2315, differs chiefly from other machines of its class in the operation of the banding-ring. To make a sharp edge at the junction of the brim and side-crown is the special object of blocking; and although the crown is also shaped, that part of the work is already done on the stretcher. The framing of the machine and the driving mechanism are substantially the same as in the power tip-stretcher just described; but in place of a former, the brim is supported by an annular plate, which is recessed in the centre to receive a hat-block of the desired size and shape. Another plate is suspended by rods from the upper cross-piece. When the treadle is depressed, and the sliding spindle with the brim-plate raised, the hat-brim is clamped and held fast between the two plates. The driving-shaft gives a vibratory motion to the side-rods, to the upper end of which a cross-head with the banding-ring is attached. The banding-ring thus has a rapid vertical motion. When the hat is placed on the block, it is clamped. The block is then raised by a hand-lever until its under side is in the same plane as the hat-brim, where it is secured by hook-latches. The operator, while keeping his weight on the treadle, now removes the hat previously blocked while the band is formed in the hat in the machine. The treadle is then lowered enough to take off the hat and block, and is allowed to descend to its lowest position to release the sliding head upon which the block rests, and permit it to drop below the surface of the brim-plate, where it is held until the hat is removed by the hook-latches already mentioned. A set of machines, namely, tip and brim stretchers and blocker, working in succession, will block from 100 to 120 dozen hats daily.

The coloring, stiffening, and washing processes are the same as already

described for fur hats. The Eickemeyer pouncing machine noted in the same connection is also largely used. Two machines are however required, a right-hand and a left-hand machine, in order to produce a nap in the same direction on both sides of the brim. This is not requisite in fur-hat making, owing to the softness of the material. It is now necessary to remove all the fine dust from the surface of the hat, and for this purpose the same machine is used. The cutting-roller is replaced by a cylindrical brush.

2816.

The treatment of wool hats in the finishing room differs from that of fur hats, in so far that the hat-body is always softened by a steam-jet when it is to be drawn on the finishing-block or shaping-flange.

Finishing.—Two methods are chiefly employed to give the wool hat its proper shape and finish. Hats with brims very much curved, and turned on the upper edge toward the crown, are first steamed, and the edge of the brim is secured to the periphery of a mould of suitable form. A second steaming follows, and the block is forced into the crown by means of a lever until its under side is even with the brim, which is thus drawn tightly over the mould. After cooling, the edge of the brim is cut, and the hat is then while on the block removed from the mould. The block is secured upon a rapidly revolving lathe-head, when the crown is first retouched with sand-paper, and finished by rubbing with a piece of felt by hand. This last is termed "ragging."

Hats with flat brims are first steamed on the finishing-block, and the band secured by a cord. The brim is flattened and ironed, and the hat is placed in the finishing lathe, rubbed with sand-paper, and ragged. Before the hat is trimmed, the crown (and, if flat, the brim) is pressed in a hot mould or on a hot plate. Fig. 2816 represents a hand-lever press used for this purpose. The hat is placed in a brass mould, and upon a hollow iron bed-plate heated by steam. By means of the cross-heads shown, the pressure upon the rubber diaphragm inside of the block is regulated. Usually three of these presses are placed in a row, and by the time a hat is placed in the last of the series, that in the first is pressed, and thus the work of pressing is continuously kept up.

In trimming hats, the principal machine to be noted is a sewing-machine which sews in the sweat-leathers. It is very ingeniously constructed, so that brims of any shape or curve may be introduced.

The large majority of the machines described in this article are the invention of Mr. R. Eickemeyer of Yonkers, N. Y., to whom we are indebted for the facts embodied in their description. G. H. B.

HAY-FORK. See Agricultural Machinery.

HAY-LOADER. See Agricultural Machinery.

HAY-RAKE. See Agricultural Machinery.

HEADERS AND STRETCHERS. See Masonry.

HEAD-FORMING MACHINE. See Barrel Machinery.

HEADING. See Carpentry.

HEARTH. See Furnaces.

HEATER, FEED-WATER. See Boilers, Steam.

HEATER, FIREPLACE. See Stoves and Heating Furnaces.

HEATING BY STEAM AND HOT WATER.

Steam-Heating.—*The Holly System of Heating Cities.*—The most extensive application of steam to warming purposes which has been made has been introduced in Lockport, N. Y., by the Holly Steam Combination Company. Through the winter of 1877–'78 about three miles of underground pipe were laid, supplying steam to forty large dwellings, a school-building, and a hall, and also to two engines, one of them nearly half a mile distant from the boiler-house. The following description and data obtained by test have been contributed by the inventor of the system, Mr. Birdsill Holly:

"It was at first claimed that a district half a mile square could be warmed with boilers located at one central point; but frequent tests along the first line of underground pipe soon began to show that a very much larger district could thus be heated. At the farther end of 1,600 feet of 3-inch pipe the water from condensed steam was trapped out and weighed for 12 hours; the result showed 15.6 cubic feet, or 31.2 cubic feet for 24 hours. Then, on the basis of 10 to 1 for evaporation, we have 31.2×62.5 (1 cubic foot) $= 1{,}950$ lbs. water $\div 10 = 195$ lbs. of coal, costing 30 cents per day. The second test was to ascertain the quantity of steam that would pass through the pipe with a pressure in the boiler of 25 lbs. The pressure at the farther end of the pipe was drawn down from 25 lbs. to 10 lbs. (a good working pressure) by letting the steam escape into the air. The coal was then carefully weighed for several hours, showing a consumption of 400 lbs. of coal per hour, or 9,600 lbs. per 24 hours, which would evaporate 96,000 lbs. of water into 2,688,000 cubic feet of steam, at the pressure of the atmosphere. Then, allowing each consumer on the line 12,000 cubic feet of steam at the above pressure, which will warm 10,000 cubic feet of space in blocks for 16 hours a day, we have $2{,}688{,}000 \div 12{,}000 = 224$ consumers to share the loss of 30 cents per day. Then the loss in the large mains is to be added, making the total loss by condensation, in a district of 24,000

consumers, 40 cents per year for each consumer with a pressure in the mains of 25 lbs. A test made in the winter with the same amount of surface, but with 32 lbs. instead of 25 in the mains, showed a loss of 10 per cent. more; but in no case can the loss be more than 60 cents per year for each consumer, even with a pressure of 50 lbs. in the mains. Consumers in a district of dwellings more scattered and exposed on all sides, requiring about 50 per cent. more steam, calling for larger and longer mains, are charged from $1 to $1.50 per year to overcome the loss by condensation. Then, on the other hand, suppose this same district of exposed dwellings were to be warmed by steam in the old way—that is, with a small boiler in each dwelling. The loss by condensation due to the steam-boiler alone (as per tests made by the writer) is from 40 to 60 lbs. of coal per day to hold 10 lbs. of steam and not draw any out. Tests were also made on evaporation with the same boilers as they were used with radiators, which showed but 4 lbs. of water with 1 lb. of coal. The cause of this low duty is the slow combustion, as a boiler large enough to warm all the rooms in a dwelling in the coldest weather is entirely too large to warm two or three rooms in mild weather. If but 10 lbs. of coal is required to do the warming, it will still require from 40 to 60 lbs. to hold steam on the boiler. It is considered reasonable to charge 50 lbs. of coal per day, or 5 tons per year, costing $20, and the interest on a steam-boiler, fixtures, and setting up, say $21, making $41 per year.

"The street-mains in Lockport are common gas-pipe, covered with asbestos, woolen felt, then hair-cloth three-fourths of an inch thick, and protected with strong manilla paper, then put inside of wood pipe 4 inches thick outside of the iron pipe; then all is covered with roofing felt. The trench is about 3 feet deep to the top of the tile, and is above all other pipes. The service-pipes are not taken direct from the wrought-iron pipes, but from stationary cast-iron junction boxes, which form the slip-joints, and receive the ends of the service-pipes. Each box is surrounded by a wall of brick or stone, with a loose cover, so as to be accessible. The above-quoted tests on condensation were made with 3-inch pipe. The per cent. of loss by condensation decreases as the pipe is enlarged. The per cent. of loss for a 3-inch pipe was 9 in 400; for a 6-inch, 18 in 2,400; for a 12-inch, 36 in 14,400; for 24-inch pipe, 72 in 80,000.

"Steam may be carried a distance of 10 miles in large pipes, and then be used for both power and warming; but this will never be called for, as all the consumers in a district of 4 square miles can be reached with mains less than 2 miles long.

"*Cost of the System.*—The estimated cost of warming a district one mile square in the city of New York or Chicago is as follows: 1. As to the amount of space to be warmed, it is assumed that at least two full stories, say 100 feet deep by 15 feet high, on each side of the street, will require steam, as in many blocks and hotels it will be used in the third and fourth stories, and more or less in the basements. Then we have $100 \times 15 = 1{,}500 \times 2 = 3{,}000 \times 2 = 6{,}000$ cubic feet of space for each lineal foot of street, including both sides. Then take say one mile of street, 5,280 feet, deduct 25 per cent. for cross streets and walls between stories, and we have about 4,000 feet left. Then $4{,}000 \times 6{,}000 = 24{,}000{,}000$ cubic feet of space to be warmed for each mile of street. Then $24{,}000{,}000 \times 10 = 240{,}000{,}000$ cubic feet for the square mile, not including the cross streets, which would add something more. Then, according to tests made at Lockport during the winter, one cubic foot of steam at the pressure of the atmosphere will warm one cubic foot of space in stores, offices, and dwellings in blocks for 16 hours, being about the average time per day that steam is used. Then 240,000,000 cubic feet of steam is required per day. Each cubic foot of steam was a cubic inch of water. Now we have 240,000,000 cubic inches of water to evaporate each day; and as 1 lb. of coal will evaporate 10 lbs. of water, and make 280 cubic feet of steam, we have $240{,}000{,}000 \div 280 = 857{,}142.8 \div 2{,}000$ (1 ton) $= 428.5$ tons $\times$ \$3 per ton = \$1,276.50 per day. Then \$1,276.50 $\times$ 200 days = \$255,300 per year of 200 days. Allowing 10,000 cubic feet of space for each consumer, we have $240{,}000{,}000 \div 10{,}000 = 24{,}000$ consumers. Then \$255,300 $\div$ 24,000 = \$11.05 per year each for coal alone.

"*Total Cost of Works to supply* 24,000 *Consumers.*

12 miles of 6-inch pipe, at $3.50 per foot	$221,000
50 boilers and fixtures set complete	150,000
Boiler-house and lot	75,000
Engineering and incidentals	50,000
Total	$496,000

Running Expenses.

Coal, wood, and other expenses	300,000
Fireman and other help	10,000
Office expenses	10,000
Collecting	8,000
Taxes and incidentals	50,000
40 per cent. on capital stock	198,400
Total	$576,400
24,000 consumers at $24	$576,000
24,000 consumers at $40	960,000

"Cost of radiators and other fixtures for 24,000 consumers, at $200 each, $4,800,000. If this work is done by the company, allowing 10 per cent. profit on the work, this would amount to $480,000."

Steam-Heating of Buildings.—The method of warming buildings by steam depends on the rapid condensation of steam into water when admitted into any vessel which is not so hot as itself. At the moment of condensation, the latent heat of the steam is given out to the vessel containing it, and this diffuses the heat into the surrounding space.

Steam is applied for heating in two ways: either by coils of pipes or combined metallic sheets (*radiators*) set up in the various apartments, which warm by *direct radiation*; or by systems of pipes over which air is made to pass, and, being heated, is sent through the building by flues. This last is called the *indirect radiation* system. The choice of direct or indirect radiation will depend on the construction of the building and on the purposes for which it is intended. Direct radiation is the most economical, for the reason that radiant heat is utilized, while in indirect radiation it is partially lost. The temperature in pipes should never be below 212°; otherwise the steam rapidly condenses to water, to get rid of which the pipes must be inclined so that the water may easily flow back to the boiler, or drip-pipes communicating with the bottom of the radiators and feed-pipe; the pipes should be so inclined that the water will flow in the same direction that the steam does.

Steam possesses an advantage over hot water in the ease of application where great inequalities and frequent alterations of level occur, and particularly where the boiler must be placed higher than the places to be heated. The original cost of steam apparatus is somewhat less than that of hot-water apparatus.

Designing of Steam Apparatus.—To proportion a boiler for a given steam-pressure, see BOILERS. The evaporating power should be 30 per cent. larger than the quantity of water condensed in the pipes. The following table shows proportions of pipes when the pressure of steam is not above 15 lbs. per square inch (saturated steam):

Connecting-pipes to Coils—Direct or Indirect Radiation.

Coil Surface.	Diameter of Pipe.	Sectional Area.
25 square feet or less.	¾ inch.	0.44 square inch.
40 " "	1 "	0.78 " "
80 " "	1¼ "	1.22 " "
160 " "	1½ "	1.76 " "
250 " "	2 inches.	3.14 square inches.

The sectional area of a branch pipe must equal the area of all connection-pipes, and the sectional area of a main pipe must equal the area of all branch pipes. The sectional area of the return-pipes from a coil or series of coils must be one size less than the respective flow-pipe to the coil. Drip-pipes should connect with all *risers* (vertical flow-pipes), the water being taken into the return-pipes or boiler. The sectional area of main pipes should be reduced as soon as practicable.*

Instead of unions for joining pipes, a coupling is commonly employed having a right- and left-hand thread which fits on corresponding threads formed on the pipe ends. Similarly, where two elbows are attached to one pipe, one elbow-thread is right- and the other left-handed. The arrangement has the advantages of cheapness and easy repair.

Arrangement of Pipes in the Mills System of Steam-heating.—In this system, the invention of Mr. J. H. Mills, steam under pressure from the generator or boiler is conducted directly upward through the main supply-pipe until it reaches the return-pipe, down which it descends until it reaches the connecting-pipe of each radiator whose valve is open. After circulating through the same, and parting with its heat, it is condensed, and the resultant water flows through the outlet or drip-pipe into the return-pipe, and directly down the latter, without hindrance or check, where it is discharged into the generator.

* From "A Manual of Heating and Ventilation," by F. Schumann, C. E., New York, 1877.

The general arrangement of piping will be understood from Fig. 2317. The supply-pipe is led as shown to any convenient point near the highest radiator, from which point the supply becomes also the return, to which the radiators are connected with a single valve, the outlet and the tee being above or below the floor, as desired. The steam entering the supply-pipe expels the contained air, not into the rooms, but into the basement, through the air-vent provided, establishing at once a circulation regardless of the radiators, which if open go immediately to work, as most of their air is drawn out by the descending circulation of the steam and water. The air is allowed to fall out of the pipes, instead of being lifted and forced out; and the pipes under this arrangement do more efficient work as soon as steam is raised and as long as it remains. The radiator now being wanted, it is necessary to open but one valve, which admits the steam and also discharges the water, the air only of the radiator being discharged into the rooms.

The Albany Steam-Trap, represented in Figs. 2318 and 2319, is a mechanical device which is convertibly either a steam-trap or a boiler-feeder. As a steam-trap it returns the water of condensation from the heating coils or pipes to the boiler, whether the same are *above* or *below* the water-level in the latter. As a boiler-feeder it supplies any deficiency of water in the generator. It consists essentially of a hollow globe, supported by one end of a lever and counterbalanced by a weight at the other. The topmost pipe is connected with the steam-space of the boiler, and is opened and closed to the globe by the automatic weighted valve seen on the top of the same. The larger pipe beneath supplies the globe or trap with the condensed water from the heating apparatus. It is provided with a check-valve opening inward. The pipe at the bottom connects the globe with the water-space of

2319

the boiler, and is furnished with a check-valve opening outward. The operation is as follows: When the globe becomes filled with a certain amount of the water of condensation, it overbalances the weight at the other end of the lever, and descends. In descending, it moves the mechanism of the steam-valve sufficiently to shift the centre of gravity of the attached weight beyond its supporting point, which allows the globe to fall and open the steam-valve. The steam-pressure closes the check-valve in the supply-pipe, and allows the water in the trap to flow into the boiler through the bottom pipe, whose check-valve opens to let it pass. When the globe has lost sufficient weight through the escape of the water, it is raised again by the weighted lever, and the steam-valve is shut by the

operation of its attendant mechanism. The water of condensation is again admitted by the opening of the check-valve in the supply-pipe, and the operation is repeated continuously. The steam-valve apparatus is so nicely adjusted that the machine cannot by any possibility rest on a centre; the valve must always be fully opened or closely shut. An air-valve is also attached to the globe, through which the air is expelled.

2320.

Fig. 2319 shows the trap in connection with the boiler and coils. It will be observed that this device does not "trap" off the water into some drain to be wasted, or into a tank from which it is to be again pumped into the boiler; but it takes the water directly from the heating-coils, whether at a point above or below the boiler is of no consequence, and returns it without loss to the boiler, at a temperature of over 200°, effecting thereby alone a saving in the cost of fuel, besides the advantage of keeping the boiler fed with pure water. There is also an advantage in the fact that this trap, like the heart action in the human body, forces and keeps up a continuous circulation, occasioning thereby a greater radiation of heat from a given surface.

Construction of Radiators.—A sectional view of Carr's radiator is given in Fig. 2320. This construction is the most approved, inasmuch as a positive circulation of steam is secured, and at the same time all trouble from the water of condensation is avoided. It will be observed in the section of the base, that between each pair of the pipes that are connected at the top there are depressions in the bottom of the base, and a corresponding partition extending from the top of the base into the depressions. When the steam is let on, the water of condensation passes along the bottom of the base, filling those depressions, passing under and covering the bottom of the partitions, forming a water-seal, and thus preventing the passage of the steam. The steam will therefore follow the course of the arrows, passing up the first pipe and down the second into the second chamber; there meeting with the resistance of the water-seal, it will pass up the third pipe, and so into the chamber, and so through any number of pipes to the discharge or return pipe; and as there is no other course for it to follow, it must necessarily expel the air and heat the whole of the pipes, while the water of condensation will fall to the bottom of the base, and pass off under the partitions to the discharge-pipe.

Warner's System of Steam-Heating by Direct Radiation.—This is one of the simplest systems of low-pressure steam-heating apparatus which possess efficient means for self-regulation. It is hardly necessary to point out that where the management of apparatus of this kind is, as must be the case, commonly left to inexperienced persons, automatic devices for confining the steam-pressure to proper limits, and governing the consumption of fuel and supply of water, are of especial importance. The boiler, Fig. 2321, is upright, and its general construction is clear from the engraving. *A* is the water-feeder, *B* the service-pipe connected with the water-pipes from the street or from a tank in the house. This water-feeder is composed of a cast-iron chamber, inclosing a lever, having at one end a copper float, and at the other a valve governing the flow of water into the boiler. When the boiler requires water, the valve opens and allows it to flow in. When it has received the proper quantity, the float rises, shuts the valve, and stops the flow of water till more is required. The water-feeder is so connected with the boiler that it is not affected by the pressure of the steam, and operates equally whether there is or is not a steam-pressure. A glass gauge on the side of the water-feeder indicates the exact height of the water in the boiler, and gives notice if from any cause

the supply fails. The tube D is a hydrostatic column connected with the bottom of the boiler, being in effect a part of the boiler itself, and is always open to the external air. Before steam is generated, the water in the tube and boiler is on a level; but when the fire is kindled and more steam is generated than is required to fill the steam-chamber and the radiators that are open to receive it, a pressure is created upon the surface of the water in the boiler, and this counterbalancing column rises. When the steam accumulates to the pressure of one pound to the square inch, the column will stand 26 inches above the level of the water in the boiler, according to a well-known law of nature. This simple process is employed to regulate the draught to the fire, as well as the accumulation and pressure of steam. To this column are attached three bowls—E, F, G—with elastic heads connecting with levers, as seen in the engraving. Into the first, E, the water rises at a given pressure, say one pound, and closes the draught to the fire by the ash-pit and draught-door M. This exclusion of air, with the radiators in operation at the same time, will prevent the increase of the pressure. But should the radiators not be open to use the steam, or the draught-door be accidentally held open, the column of water will continue to rise, until at the pressure of 1¼ lb. it flows into the second bowl, F, and lifts the lever attached to the feed-door L, which opens and causes the draught to pass over the fire instead of underneath and through it. This reversal of the draught has the effect to deaden the fire at once and stop the generation of steam. A slight additional pressure forces the water of the column into the third bowl, G, and lifts the lever attached to the escape-valve H, which allows all excess of steam above that pressure to pass freely off through the waste-pipe I. C C are wrought-iron steam-pipes for conducting the steam from the boiler to the radiators. The radiators are made of two plates of bloom-iron. The front plate is stamped with conical depressions about three-eighths of an inch in depth, 2¼ inches in width, and 3¼ inches from centre to centre. The back plate is plain, and the two are riveted closely together, with copper rivets at each point of indentation, and the edges of each plate are twice doubled, or double-seamed over a leaded packing cord, and hammered down to a smooth bead about one-fourth of an inch in width.

2821.

2822.

This concave surface gives strength to the radiators, and adds much to their radiating power. The entire thickness of the radiator is about half an inch. On one of the lower corners of the radiators is a valve to open when steam is to be admitted, and closed when steam is to be excluded. An air-key is placed on the opposite upper corner, to regulate the amount of steam to be admitted. No steam will enter any part of the radiator until that part is emptied of air. By closing this air-key when any desired portion of the radiator is heated, the other portion will remain inoperative and cold. In Fig. 2822 is a radiator of this type, shown attached to the boiler.

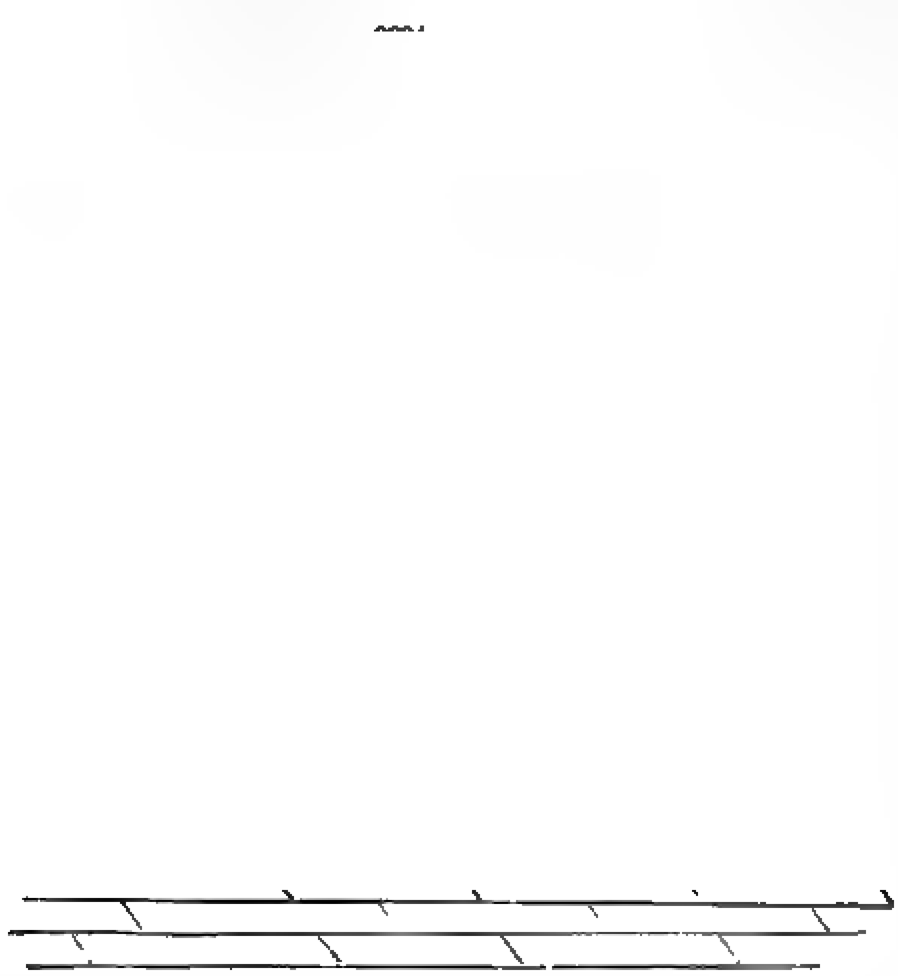
Instead of placing radiators directly in the rooms in large buildings, such as hotels, they are sometimes inclosed in cases in the walls, usually under the windows. Each case has a register which opens into the apartment. Steam is kept on constantly, and instead of graduating the heat by operating valves connected with the radiator, the occupant of the room does so by opening the register more or less.

Steam-Heating by Indirect Radiation.—In Fig. 2323 is represented Messrs. Baker, Smith & Co.'s arrangement for warming and ventilating by indirect radiation; that is, by having the heating stacks or radiators placed below (in the cellar or some lower room) instead of within the rooms to be warmed. At the left is shown the boiler, with its fire-regulating attachments, water-feeder, safety-vent, etc. At the right of the boiler are heating-stacks within chambers. To these chambers is connected an air-duct, through which fresh outdoor air passes to be heated. The heating-stacks, as shown, are connected with the boiler by two pipes; the upper one supplies the steam, and the lower one returns the water of condensation to the boiler. Two rooms on the first floor above the apparatus are represented as being warmed and ventilated. Any number of rooms directly over, on other floors, can be warmed and ventilated from the same heating-chamber; and any number of heating-chambers can be supplied, to suit the size of the building.

HEATING BY HOT WATER.

Hot-water apparatus may be resolved into two distinct forms or modifications, dependent on the temperature of the water. In the first form the water is at or below the ordinary temperature of boiling. In this arrangement the pipes do not rise to any considerable height above the level of the boiler, so that the apparatus need not be of extraordinary strength. One pipe rises from the top of the boiler, and traverses the places to be warmed, and returns to terminate near the bottom of the boiler. Along this tube the heated water circulates, giving out its heat as it proceeds. The boiler may be open or closed. If open, the tube when once filled with water acts as a siphon, having an ascending current of hot water in the shorter leg, and a descending current of cooled water in the longer leg. If the boiler be closed, the siphon action disappears, and the boiler with its tubes becomes as one vessel. In the second form of apparatus, the water is heated to 350° and upward, and is therefore constantly seeking to burst out as steam, with a force of 70 lbs. and upward on the square inch, and can only be confined by very strong or high-pressure apparatus. The pipe is of iron, about an inch in diameter, made very thick. The length extends to 1,000 feet and upward; and where much surface is required for giving out heat, the pipe is coiled up like a screw. A similar coil is also surrounded by the burning fuel, and serves the place of a boiler.

The Baker, Smith & Co. Hot-Water System.—In this system the entire apparatus, except a space provided for air, is filled with water, the joints being made absolutely tight. When the apparatus is firmly screwed together on the premises where it is to be employed, the air from the interior is expelled by means of a pump. By the same pump the whole is then subjected to a hydrostatic test of at least 400 lbs. pressure to every square inch, with a view to permanency. Then water, which is saturated, or nearly so, with salt to prevent freezing, is pumped in, till the entire internal space, with the exception of an air-chamber, is full of water. When the whole apparatus has been proven to be perfectly water- and air-tight, it is sealed by the safety-valve, and, as no evaporation is allowed, theoretically no more water need ever be added, but practically an occasional addition of a small quantity is required. Immediately on the application of fire in the boiler, the adjacent water feels its influence, and begins to circulate and impart a gentle warmth to the radiating pipes. As the fire increases, so does the temperature of the water and the pipes, rising through all the grades of temperature from lukewarm to that of steam, till the desired degrees of heat are reached. Besides the regulation at the boiler, the heat of the water radiator, when placed within a room, is nicely graduated by a single valve. By turning this valve the aperture for the flow of the water is reduced, and it circulates proportionately cooler. In this manner one room may be warmed by tepid water, while other rooms have the full heat of the water.



A portable apparatus of this kind for heating railway cars is represented in Fig. 2324. It consists of a simple fire-proof stove, occupying only two feet circle of floor space in one corner of the car; a dull fire, that consumes but about a peck of coal in 12 hours, warms the water, which circulates

through pipes run under each seat entirely around the car, giving each passenger the most agreeable foot-warmer of hot water, the heat of which is evenly maintained against all currents of air, and is unaffected by the motion of the car. By this plan, nearly the entire heat of the fire, instead of concentrating at the stove, is taken up and distributed at the very point where heat is required.

Cowan's System of Hot-Water Heating, illustrated in Fig. 2325, is largely used in Europe for heating greenhouses. It embodies a means of utilizing the waste heat of a lime-kiln. *L* is an egg-shaped kiln-chamber about 8 feet in depth. *C* is the main boiler, serving as a cover to the kiln. *D* is an annular boiler, communicating with the boiler *C* through the pipes *F*. *G G* are the return-mains, completing the circulation for the return of cooled water to the boilers, and also for keeping open communication with the expansion-cistern *H*. This cistern *H* acts as a safety-valve for the whole apparatus. The condensed water from it is returned to the annular boiler *D* through the perpendicular pipe *I*. *M* is a valve in the flow-pipe to the expansion-cistern *H*. The pipes *E* communicate with all the premises to be warmed, and through the valve *M* with the compensating cistern *H*. A blow-off cock for the annular boiler is necessary. A complete circulation of any length is claimed for this apparatus, which can be erected anywhere outside the buildings to be heated. In the extensive hothouses of Hatfield Park, England, 7,000 feet of 4-inch pipe are heated in this way, and one consumer uses the furnace or kiln for the manufacture of coal-gas, obtaining this commodity at a very moderate expense. The kiln is also used for lime-burning, the product being sold, and the expense of heating is thus reduced.

HEDDLE. See Looms.

HEEL-FORMING MACHINE. See Shoe Machinery.

HEEL-POLISHING MACHINE. See Shoe Machinery.

HOISTING ENGINES. See Elevators, Engines (Steam Hoisting), and Mine Appliances.

HOISTS. See Elevators.

HOLLANDER. See Paper-making Machinery.

HORSE-POWER. For discussion of this term as the measure of the capacity of a motor, see Engines, Designing of, and Dynamics. The name is also applied to mechanism by which the strength of a horse is advantageously utilized for driving machines of various kinds.

Figs. 2326 and 2327 represent Bogardus's horse-power arranged for different purposes. The base-frame is cast into one piece, consisting of the central hub and the outer ring, connected by radial arms and standing on legs. The central hub is cast with a hollow standard properly turned with a slight taper, to which is fitted a sleeve that turns thereon freely but accurately, and resting on the upper surface of the hub, and likewise with this sleeve, and making part thereof, is cast a wing, to which is secured by bolts the horse-beam or lever by which the whole is operated. The other end of the wing is provided with another sleeve cast therewith, and parallel to the first, to which is fitted accurately (but so as to admit of turning freely) the arbor of the planet-wheel and planet-wheel pinion, the former being at the top and the latter at the

bottom. One of these, either the wheel or the pinion, can be permanently attached to the arbor, and the other keyed on after it has been inserted in the sleeve. The cogs of the pinion of the planet-wheel take into the cogs formed in the inner periphery of the rim of the base-frame, and this may be called the master-wheel; and the cogs of the planet-wheel take into the cogs of and drive the central pinion on the upper end of a vertical shaft that passes through and turns freely but accurately in the central hollow standard, which is adapted to it, the driving-pulley being keyed on the lower end and below the hub. A band from the driving-pulley can be carried under the frame and between the legs to any place required, in the usual manner, to drive any piece of machinery; but if desired, the driving-pulley can be attached to the central shaft above the central pinion.

2327.

Fig. 2327 shows the apparatus as arranged to carry the belt from the horizontal pulley under the foot-path on which the horse walks. As represented in Fig. 2326, the shaft may be carried under the foot-path or to a floor above. The diameter of the path should be from 25 to 30 feet, and the speed of the horse should be at the rate of about 2½ miles per hour.

Fig. 2328 represents a form of horse-power arranged on a different principle from the foregoing. In this the weight of the horse as well as the animal's muscular power is utilized. The wooden step-boards *D* are arranged in an endless belt, and are supported by a series of small rollers which rest on inclined tracks or ways. The apron passes over and rotates the drum *A*, which by a pinion turns a gear, on the opposite end of the axle of which is a wheel, which is governed or held by a brake-lever. The horse walks upon the step-boards, and so causes the apron to rotate. Power is taken off by suitable belting.

A similar arrangement for utilizing horse-power in driving a railway car is represented in Fig. 2329, the device being termed an "impulsoria." Motion is imparted from the moving platform to the axles by means of gearing. It is hardly necessary to point out that this is simply an ingenious way of wasting power, and that the force of the animal would be much more economically exerted by direct traction of the vehicles.

HORSE-POWER (H. P.). See Engines, Heat.
HORSE-SHOE MACHINERY. See Forging.
HOUSING. See Carpentry.
HULLERS, COFFEE AND RICE. *Coffee Hullers* are machines for removing the husk or hull from coffee grains.

Brown's Huller.—In the apparatus constructed by Messrs. W. A. Brown & Co., of Lynn, Mass., represented in Fig. 2329 A, the hulling is accomplished by drawing the grains on an endless chain or apron consisting of a series of corrugated iron pads, which are made to pass underneath a series of steel keys or fingers held in place by coiled steel springs, causing them to adjust themselves to the size of the beans which pass under them, so that a small bean cannot pass through unhulled and a large bean passes through unbroken; thus hulling both small and large beans. The coffee and the hulls fall from the hulling plates, or pads, on to a set of sieves, which are so arranged that they are continually in motion and keep the hulls and coffee in line of the current of air produced by the fan which is located in the front part of the machine, and is arranged so as to blow out the hulls and

2329 A.

allow the coffee to fall through the sieves on the chute, which conducts it into the receptacle placed to receive it.

The coffee being free from hulls, it is necessary to give it a thorough cleaning and polishing, thereby removing the fine silver skin which closely adheres to the beans. An improved device for this purpose by the above-named makers consists of a heavy perforated brass cylinder arranged horizontally in a heavy wooden frame. Through the cylinder passes a shaft on which are a number of hard-wood floats. The shaft rotates at the rate of about 100 revolutions per minute. By means of the floats the coffee is thoroughly agitated, and thus cleaned and polished.

Guardiola's Huller.—The coffee-hulling and polishing machine devised by Sr. José Guardiola, of Guatemala, consists essentially of a mortar and pestle, the construction being such that the coffee is cleaned and polished by the friction of one grain against the other moving in the broken chaff. The pestle is a sieve having on its surface oblique projecting ribs, set at proper distances from one another so as to form channels. The interior of the mortar is also provided with ribs and channels. The pestles drop simultaneously into the mortars, and the coffee is forced to move up and down the channels. The husk is broken, and finally pulverized. Each mortar, it is claimed, will clean from 150 to 200 lbs. of coffee per hour.

Squier's Coffee Huller, it is claimed, makes the coffee in a large degree hull itself, by forcing the grains to rub against each other under pressure, thus preventing all breakage of the grains and polishing them during the process of hulling. An iron cylinder is provided through which runs a

screw with peculiar broken threads. At one end of the cylinder is a hopper into which the coffee is fed, and a peculiar propeller forces the coffee into the cylinder, where the screw keeps the grains in constant agitation, grinding against each other until the husk is broken and the silver skin worn off, and the coffee comes out hulled and polished. It has then only to go to the separator to have the chaff blown off and the grains sorted according to size, when it is ready for market.

Rice Huller.—The essential requirement of this machine is to hull the rice without breakage. An ingenious machine for this purpose, made by Messrs. George L. Squier & Bro. of Buffalo, N. Y., consists of two disks running one on the other like millstones. The upper disk is stationary, and the lower one, instead of having a rotary motion like a millstone, has a reciprocating motion. The unhulled rice passes from the hopper through an eye in the centre of the upper disk, and, the disks being grooved in a peculiar manner, the rice spreads over the face of the lower disk, and is rolled and rubbed between the two disks until the hulls are removed, when it passes out over the edge of the lower disk and falls into a receptacle. Increased capacity is attained by multiplying the disks, all being put into one frame and actuated by a single pitman. In all rice there is a certain amount of small, green, shriveled, or imperfect grains, that will pass through any huller unhulled; and one difficulty of rice-hulling has been to dispose of these. It is too expensive to pick them out by hand, and therefore it has been the custom in rice-mills to dump all the rice as it comes from the hulling stones into mortars, and pound it until the hulls ore worn off from these few unhulled grains. A separator has been devised by the above manufacturers which is claimed to separate the unhulled from the hulled grains, and to clean rice and save every grain with little or no breakage.

HYDRAULIC ENGINE. See ENGINES, WATER-PRESSURE.

HYDRAULIC FORGING. See FORGING.

HYDRAULIC MAIN. See GAS APPARATUS.

HYDRAULIC PRESS. See PRESS, HYDRAULIC.

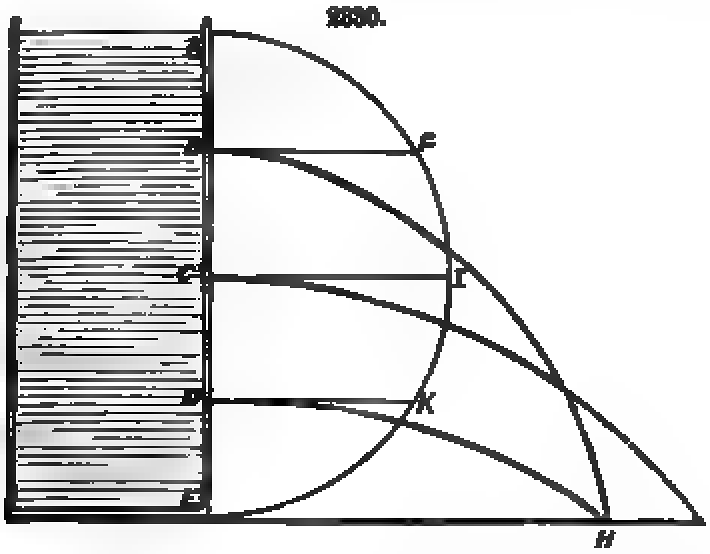
HYDRODYNAMICS treats of the laws of liquids in motion. One of its most important principles is that which determines the velocity of jets which issue from orifices at various depths in the sides of vessels containing liquids, and depends upon the laws of hydrostatic pressure. If an orifice is made in the side of a vessel containing a liquid, the liquid will issue from it with a velocity equal to that which a heavy body would acquire in falling through the vertical distance between the surface of the liquid and the orifice. If the jet is directed upward, it will ascend, theoretically, to a level with the surface of the liquid; but practically it will fall short of this in consequence of friction at the orifice, and of the resistance offered by the air. At first sight it would appear that the velocity of efflux would be proportional to the pressure; but an analysis of the case, apart from the test of experiment, will show that this cannot be, for in no case can the jet be projected higher than the surface of the liquid. If, in general terms, the velocity of a jet were in proportion to the pressure at the point of issue, a column of mercury would throw a jet with 13½ times the velocity that an equal column of water would; but it must be perceived that a column of mercury can only propel a jet as high (theoretically) as the surface, and therefore to the same height as an equal column of water can. Now, there can be no doubt that the pressure of mercury at the same depth is 13½ times that of water; but mercury, being also 13½ times as heavy as water, has 13½ times as much inertia, and therefore requires so many times as much force to give it the same initial velocity. The velocity with which a liquid escapes from an orifice varies as the square root of the depth below the surface; so that when the points of escape are 1, 4, 9, and 16 feet in depth, the initial velocities will be as 1, 2, 3, and 4. This is the celebrated theorem of Torricelli, which he deduced from the laws of falling bodies. As the velocity of a falling body is in proportion to the time of its fall, it will be in proportion to the square root of the height fallen through, and is represented by the ormula $V = \sqrt{2gh}$, in which g is the accelerating force of gravity (= 32.2), and h the height. (See DYNAMICS.) A jet issuing from the side of a vessel describes, theoretically, a parabola, precisely as in the case of a solid projectile; for the impelling force and the force of gravity act upon the jet in the same manner, and the resultant force gives it the same direction. The range, or distance to which the jet is projected, is greatest when the angle of elevation is 45°, and is the same for elevations which are equally above or below 45°, as 60° and 30°. The resistance of the air however alters the results, and the statement is only true when the jet is projected into a vacuum.

If a vessel filled with water have orifices made in its side at equal distances in a vertical line from the top to the bottom, a stream issuing from an orifice midway between the surface and the bottom will be projected farther than any of the streams issuing from the orifices above or below. This may be demonstrated by the adjoining diagram, Fig. 2330. Let a semicircle $A\,F\,E$ be described on the side of a vessel of water, its diameter being equal to the height of a liquid. The range of a jet issuing from either of the orifices B, C, or D will be equal to twice the length of the ordinates $B\,F$, $C\,I$, or $D\,K$ respectively; and therefore jets issuing from B and D will meet at a point H on a level with the bottom, and twice the length of the ordinates $B\,F$ and $D\,K$. Now, as the ordinate $C\,I$ is the greatest, the range of the jet issuing from C will be greater than that of any other jet. The amount of water escaping in one second from an orifice would, theoretically, be equal to a cylinder having a diameter equal to that of the orifice, and a length equal to the distance through which a body will move with a uniform velocity after it has fallen through a height equal to the vertical distance between the surface of the liquid and the orifice. If this distance is 16.1 ft., the velocity acquired will be 32.2 ft. per second, and therefore the theoretical quantity discharged from an orifice 4 in. in diameter, whose centre is 16.1 ft. below the surface, would be equal to a cylinder 4 in. in diameter and 32.2 ft. long, and containing 4,828.5 cubic inches, or about 21.83 gallons.

The actual discharge from a thin orifice not furnished with an ajutage is however much less, being only about two-thirds of the theoretical amount. The loss is owing partly to friction, but mainly to the interference of converging currents moving within the vessel toward the orifice. This interference may be shown by employing a glass vessel having a perforation in its bottom, as represented in

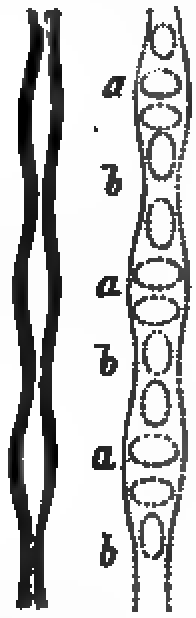
Fig. 2331. If particles of some opaque substance having nearly the same specific gravity as water, so that they will remain suspended in it for a space of time, be mingled with the water, they will be seen to move in the direction indicated by the lines in the figure, which are nearly direct. If the jet is carefully observed, it will be seen that it is not cylindrical, and that for a distance from the orifice

2330.



2331.

2332.



of about half its diameter it resembles a truncated cone with the base at the orifice. This contraction of the stream is called the *vena contracta*, and its smallest diameter is stated to be from 0.6 to 0.8 of that of the orifice. When the stream has a direction downward nearly vertical, it continues to diminish beyond the vena contracta, in consequence of the increased velocity caused by the force of gravity, the size being in the inverse proportion to the velocity. The increased velocity at the vena contracta is due to the pressure which forces the particles of water into a narrower channel. As the jet continues to fall, it forms a series of ventral and nodal segments, as shown in Fig. 2332. The ventral segments are composed of drops elongated horizontally, as seen at *a a a*, while the nodal segments are elongated vertically, as seen at *b b b*; and as the segments have fixed positions, it follows that the drops in falling are alternately elongated vertically and horizontally. If the orifice is in the side of the vessel and discharges horizontally, the size of the stream does not diminish in the same manner as when falling vertically, and it is sooner broken. If a cylindrical tube or ajutage whose length is from two to three times its diameter is fitted to the orifice, the rate of efflux may be increased to 80 per cent. of the theoretical amount. The velocity will be somewhat diminished, but the vena contracta will be larger in proportion. If the inner end of the ajutage has a conical shape with the base toward the interior, the efflux may be further increased to 95 per cent.; and it has been found that if the outer end of the tube is also enlarged, the efflux may be still further increased to very nearly the theoretical amount, say 98 per cent. When a cylindrical ajutage is used, there will be a partial vacuum formed between the sides of the tube and the contracted vein, as shown in Fig. 2333. If a pipe ascending from a reservoir of water is let into this part of the ajutage, the water will rise in the pipe; and if the height is not too great, the vessel may be emptied.

2333.

The resistance offered by conduits is a subject of great importance in practical hydrodynamics, upon which extended experiments have been made. When the length of the ajutage bears more than a certain proportion to its diameter, the efflux is reduced to about the same amount as when the stream issues through a thin orifice, that is, about 62 per cent. of the theoretical amount. With a pipe 1½ in. in diameter and 30 ft. long, the efflux will be only about half that from a thin orifice, or 31 per cent. of the theoretical amount. This reduction is caused by friction between the liquid and the tube, as well as between its particles, and is greater with cold than with warm liquids. This resistance to motion, or approach to rigidity, which is conferred by cold, is called viscosity, and is a principle which has to be taken into account in nearly all very careful hydraulic calculations.

Resistance of Liquids to the Motion of Solid Bodies.—This will depend upon the form and size of the body. The following are two important laws: 1. With the same velocity, the resistance is proportional to the extent of surface applied by the solid to the liquid in the direction of motion. 2. With the same extent of surface, the resistance is proportional to the square of the velocity. These laws may be demonstrated experimentally, but their truth will also be apparent from the following considerations. In regard to the first law, it will be easily understood that with the same velocity the amount of water displaced will be the measure of resistance, and that a surface of two square feet will displace twice as much as one of one square foot. The second law is not so evident, but will be made clear by considering that with a given surface, when the velocity is doubled, twice the quantity of liquid will move through twice the space in the same time, and will therefore, according to the principles of mechanics, have a fourfold momentum. The resistance, therefore, offered to a plane surface moving at right angles against a liquid, is measured by the area of the surface multiplied into the square of the velocity. It has been found that a square foot surface, moved through

water with a velocity of 32 ft. per second, meets with a resistance equal to a weight of 1,000 lbs. When the motion of a body in a liquid is very slow, say less than 4 in. per second, depending on the size of the body, the larger body requiring to move more slowly, the above laws are not rigidly followed, but the resistance is divided into two components, one of which is proportional to the simple velocity, and the other to the square of the velocity. The most accurate results in experimenting with slow motions were obtained by Coulomb, who used his torsion balance. One of the most interesting problems in mathematics has been to determine the form of a solid which will meet with the least resistance in moving through water. This form is called the "solid of least resistance," and is approached as near as practicable in the construction of ships.

The complete demonstration of the principles of hydrodynamics involves the higher mathematics, and their elucidation in full would require greater space than can here be afforded. For this the reader is referred to the special treatises on the subject.

For a full discussion of Herr Kutter's new formula for mean velocity of discharge of rivers and canals, see a work bearing that title, translated by Louis D'A. Jackson, A. I. C. E. (London and New York, 1876); also, for a complete exposition of the science, "Hydraulic Manual and Statistics," by the same author. The following works may also be consulted: "Practical Hydraulics," by Thomas Box (4th edition); "Manual of Hydrology, containing Hydraulic and other Tables," etc., by Nathaniel Beardmore, C. E.; Tredgold's "Tracts on Hydraulics"; "Hydraulic Engineering, a Prize Essay on the Encroachment of the Sea between the River Mersey and the Bristol Channel," by J. E. Thomas (1866); "Hydraulics of Great Rivers, being Observations and Surveys on the largest Rivers of the World," by J. J. Révy, with plates and charts; "Mechanics of Fluids," by Alexander Jamieson, LL.D.; "Engineers' Pocket-Books" of Haswell, Molesworth, and Trautwine; "A Descriptive and Historical Account of Hydraulic and other Machines for raising Water," by Thomas Ewbank (16th edition). See also AQUEDUCT, BARRAGE, CANALS, DRAINAGE, PUMPS, WATER-WHEELS, and WELL-BORING.

HYDROMETER, or AREOMETER.* An instrument for determining the specific gravity of liquids. It generally consists of some buoyant body, as hollow glass or copper, weighted at the bottom and supporting a graduated stem, or one having a definite mark. There are two kinds, those of constant and those of variable immersion. Those of constant immersion are made to sink in the tested liquid, whether dense or light, to the same depth, by balancing with weights. Those of variable immersion have no movable weights, but rise or fall according to the density of the liquid.

Nicholson's hydrometer, Fig. 2334, is of the first kind. As usually constructed, when this instrument is immersed in water it requires a weight of 1,000 grains to make it sink to a certain mark on the stem. According to the principle of Archimedes, the weight of the instrument, together with the 1,000 grains which it sustains, is equal to the weight of the volume of water displaced. If the instrument is placed in a liquid lighter or heavier than water, and the weight changed until it sinks to the same depth, the specific gravity of the liquid will be indicated by the formula $g = \frac{W + w}{W + 1{,}000}$, where W is the weight of the instrument, and w that of the weights placed upon the pan. If w is less than 1,000 grains, it will show that the liquid is lighter than water; and if it is more than 1,000 grains, it will show that it is heavier. This instrument may also be used to find the specific gravity of solids, or as a delicate balance. For these purposes it has a small cup or wire cage suspended at the bottom to hold the body, which may be either heavier or lighter than water. To find the specific gravity of a solid, let it be first weighed in air, by placing upon the pan a piece of the substance which weighs less than 1,000 grains. Suppose the substance to be sulphur, and that 440 grains are required to be added to make the instrument sink to the mark on the stem, the weight of the sulphur is, evidently, $1{,}000 - 440 = 560$ grains. Now, what it loses if weighed in water will be the weight of an equal bulk of water, and this will be found by placing it in the cup or cage at the bottom, and adding sufficient weights to those in the pan at the top to bring the mark to the level of the water. If it requires the addition of 275.2 grains, that amount will represent the weight of a volume of water equal to the sulphur; consequently the specific gravity of the sulphur will be $\frac{560}{275.2} = 2.03$. If the body is lighter than water, it will of course require the addition of more than its weight to the pan, and for immersion it will require to be placed in the wire cage.

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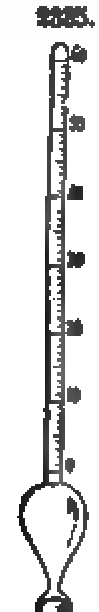

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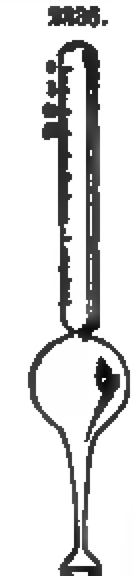

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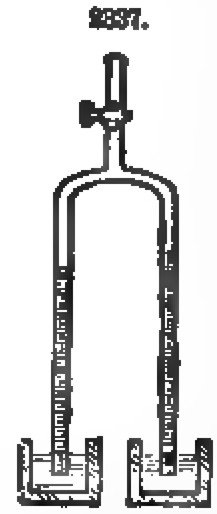


* From the "American Cyclopædia."

Fahrenheit's hydrometer differs from Nicholson's in being constructed of glass, and having a constant weight of mercury in a bulb at the lower end. Its use is therefore restricted to the weighing of fluids.

Of hydrometers of variable immersion, Baumé's is the one most frequently used, and furnishes a good example of the class. Two instruments, of different forms, are represented in Figs. 2335 and 2336. They are made of glass; their stems are hollow and lighter than the fluid in which they are immersed. Fig. 2335 is called a salimeter, and is used for estimating the proportion of a salt or other substance in solution. It is graduated in the following manner: Being immersed in water at a temperature of 12° C., the point to which it sinks is marked 0°; it is then placed in a solution containing 15 parts of common salt to 85 of water, the density of which is about 1.116, and the point to which it sinks is marked 15, and the interval divided into 15 equal parts; the graduation is then extended downward, generally terminating at 66°, which corresponds to the density of sulphuric acid. When the instrument is to be used for liquids lighter than water, the zero is not placed at the point to which it sinks in pure water, but at a point to which it sinks in a solution containing 10 parts of common salt to 90 of water. The point to which it sinks in pure water was marked by Baumé 10°, and the graduation was continued upward to the highest point to which the stem might be immersed in the lightest liquid. Fig. 2336 represents the instrument for liquids lighter than water. The graduation of these hydrometers is arbitrary, and is an indication of the strength of the liquid only after trial.

Hare's hydrometer, a very valuable instrument, but one which has not been much employed, acts upon the principle of the barometer, and yields directly results of definite comparison; it is represented in Fig. 2337. A ∩-shaped tube has its legs, of equal length, placed in shallow vessels, one containing the liquid to be tested, and the other a liquid taken as a standard, as water. A partial vacuum is then produced in the tube by exhausting the air by means of an air-pump, the mouth, or otherwise, making use of the stop-cock to facilitate the operation. It is evident that the height of the liquid column will be in the exact inverse proportion to the specific gravity of the liquids.

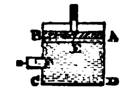
Hydrometers have various names, according to the purpose for which they are used: as lactometers, for estimating the amount of cream in milk, or the quantity of sugar of milk in the whey; vinometers, for estimating the percentage of alcohol in wine or cider; and there are acidometers and saccharometers.

HYDROSTATICS. The mechanical properties of liquids are determined on the hypothesis that liquids are incompressible. They are, however, more compressible than most solids. If a cubic inch of water be pressed with 15 lbs. on each and every side, the volume will be diminished $\frac{1}{20000}$; hence 1 lb. pressure to the square inch will diminish the volume $\frac{1}{300000}$. If the water be confined in a perfectly rigid prismatic vessel, the compression would take place entirely in the direction of the length, and would equal $\frac{1}{300000}$ of the length for every pound per unit of area of the end pressure. Water therefore is nearly 100 times as compressible as steel. All other liquids are more or less compressible; yet, for most practical purposes, they may be considered as non-elastic without involving sensible error. Liquids are sometimes defined as non-elastic bodies.

The upper surface of a liquid contained in a vessel which receives no pressure is called the free surface. The upper surface of water in the atmosphere is pressed downward by the air with about 15 lbs. to the square inch; yet such a surface is often considered as a free surface. The free surface of small bodies of a perfect liquid at rest may be considered as horizontal, for it will be perpendicular to the action of gravity; but for large bodies of liquid it is spherical, partaking of the general form of the surface of the earth. A level surface is one which cuts at right angles the resultant of the forces which act upon its particles. Thus, in a vessel filled with a heavy liquid at rest, it is horizontal; in the ocean, it may be a surface at any depth and nearly concentric with the free surface. In a cylindrical vessel containing a perfectly homogeneous liquid, if the vessel be revolved uniformly about a vertical axis, the surface becomes a paraboloid of revolution. In a vessel filled with a perfectly homogeneous liquid and drawn horizontally with a uniform acceleration, the free surface becomes a plane. If a perfectly homogeneous mass of liquid be acted upon by a force which varies directly as the distance from the centre of the mass, the free surface will be of spherical form; if the mass rotates about an axis, the form assumed will be that of an oblate spheroid, which is the shape of the earth.

It will be obvious from the foregoing that each particle of a liquid must exert and receive equal pressures in all directions. If this were not true, the particles of a liquid could not come to a state of rest. From this principle it follows that equal surfaces of the sides of a vessel containing a liquid receive equal pressures at equal depths below the surface; and also that if a closed vessel be filled with a liquid which we will suppose to have no weight, and if an aperture of the size of 1 square inch be made in one side of it and fitted with a piston upon which there is exerted a pressure of 10 lbs., there will also be exerted the same pressure of 10 lbs. upon every square inch of the lateral surface of the vessel. Consequently, if another aperture of 100 square inches area be made in the side of the vessel, and a cylinder of the same size be fitted to it, a piston fitted to this will receive a pressure of 1,000 lbs. Upon this principle the hydraulic press is constructed.

2338.



In Fig. 2338, let E represent the large piston in the vessel $A\ B\ C\ D$, and F the small one. Let P represent the pressure on piston E, A the area of the orifice in which this piston enters, p the pressure on piston F, and a the orifice to which this piston is fitted. Then, according to the principle noted above, $a : A :: p : P$. But the areas of different circles are to one another as the squares of their diameters. Representing these areas by d and D, we have $d^2 : D^2 :: p : P$, in which these values are substituted in the first-noted equation. From this ratio we obtain $p\,D^2 = P\,d^2$. From this we have the following rules, the application of which to the designing of hydraulic presses will be obvious:

To find the intensity of the pressure on the cylinder-piston, multiply the square of the diameter of the cylinder by the pressure on the piston of the forcing-pump, and divide the product by the square of its diameter; or the formula, $P = \frac{P D^2}{d^2}$.

Example.—If the diameter of the cylinder is 5 inches and that of the forcing-pump 1 inch, what is the pressure on the piston in the cylinder, supposing the pressure applied on the small piston to be equivalent to 750 lbs? $P = \frac{5^2 \times 750}{1^2} = 18{,}750$ lbs.

To find the pressure on piston F, or power required, we have $p = \frac{P d^2}{D^2}$.

The diameter of the cylinder is obtained by the formula $D = \sqrt{\frac{P d^2}{p}}$; and the diameter of the forcing-pump is given by the formula $d = \sqrt{\frac{p D^2}{P}}$. These are very easily applied, as indicated by the practical example already given.

In designing hydraulic presses the following data will also be found useful:

To determine the thickness of metal in the cylinder to withstand the required pressure: The amount of force which tends to rupture the cylinder along the curved side, that is, to divide the cylinder in halves lengthwise, is equal to the pressure per square inch on each lineal unit of the diameter multiplied by the length of the cylinder. Thus, let the piston of a hydraulic press be 10 inches in diameter, and the pressure 300 tons net; then the pressure per square inch of piston will be 300 tons divided by the number of square inches in the piston, or $\frac{600{,}000}{78.54} = 7.639$ lbs. The pressure per inch in length of the cylinder tending to split or tear it apart is equal to the diameter multiplied by the pressure per square inch; or in this case, $10 \times 7639 = 76{,}390$ lbs., of which, of course, each side sustains one-half.

An English rule for the construction of cast-iron cylinders is to make the thickness of metal equal to the interior radius of the cylinder, and to determine the entire pressure in tons. When the diameter of the cylinder is given, the following simple rule is used: Multiply the square of the diameter in inches by the constant number 2.9186, and the product will be the pressure in tons. And again, when the pressure in tons is given, the diameter of the cylinder may be determined by reversing the process, or by the following rule: Divide the given pressure in tons by the constant number 2.9186, and extract the square root of the quotient for the diameter of the cylinder in inches.

Example.—The diameter of the cylinder in a hydrostatic press is 10 inches; what is its power, or what pressure does it transmit? Here, by the first rule above, we have $P = 10^2 \times 2.9186 = 291.86$ tons.

Example.—What is the diameter, and what the thickness of metal, in a press of 300 tons power? By the second rule above, we have $D^2 = 300 \div 2.9186 = 102.81$ nearly. Therefore, by extracting the square root, we obtain $D = \sqrt{102.81} = 10.13$ inches. Consequently, the thickness of metal is, $t = 10.13 \div 2 = 5.065$ inches.

Examples of mechanical construction of hydraulic presses will be found under PRESSES.

The Hydrostatic Bellows, shown in Fig. 2339, acts upon the same principle as the hydrostatic press; the cover of the bellows, upon which the weight is placed, performing the office of the large piston, while the column of water in the tall vertical pipe acts the part of the small piston of the press. The hydrostatic bellows also illustrates the principle of the hydrostatic paradox, for the vertical pipe and bellows are virtually one vessel, the base of which is the bottom of the bellows. The pressure exerted by the liquid in the pipe upon the upper plate of the bellows is received by the lower plate, which also has an additional pressure equal to its distance below the upper plate; and if the water in the pipe is ten times as high as that in the bellows, it follows that the pressure on the bottom plate will be ten times as great as that which would be produced by the liquid contained within the bellows itself, for that is only equal to its own weight. If a barrel of water therefore have a tall tube inserted in one head and standing vertically, a pressure may be produced on its bottom several thousand times that due to the weight of the water alone. In accordance with this law of hydrostatic pressure, a liquid will rise to the same height in different branches of the same vessel, whether these branches be great or small. Thus, water contained in the U-shaped vessel, Fig. 2340, will rise to the same height in both branches, which is an illustration of the principle that the pressure of a column of liquid is in proportion to its height and not to its quantity. This principle, however, if it is entitled to such a name, proceeds directly from the principle of Archimedes that each particle in a liquid at the same depth receives an equal pressure in all directions. If, however, one leg of a U-shaped tube contain mercury and the other water, the column of water will stand 13½ times as high as that of mercury.

It follows from the fact that a liquid presses equally upon equal areas of a containing vessel at the same depth, that if a hole is made in one side of a vessel, less pressure will be exerted in the direction of that side; and therefore, if the vessel is floated on water, as in Fig. 2341, it will be propelled in the direction of the arrow. Barker's centrifugal mill, a small model of which is shown in Fig. 2342, acts upon the same principle of inequality of pressure on opposite sides. The propelling force has been ascribed to the action of the escaping liquid pressing against the atmosphere, by which a corresponding reaction is obtained; but if the machine is placed in a vacuum, it will rotate with greater velocity than in the open air, which proves that the propelling force is the preponderance of pressure in one direction.

LAWS OF PRESSURE.—1. The hydrostatic pressure against equal areas of the lateral surfaces of

cylindrical or prismoidal vessels, beginning at the surface of the liquid, varies as the odd numbers 1, 3, 5, 7, etc. 2. The hydrostatic pressure against the entire lateral surfaces of cylindrical or prismoidal vessels is proportional to the square of the depth. The first law is demonstrated as follows: Hydrostatic pressure in any direction at any point in a liquid is in proportion to the depth, a result due to the action of gravity; therefore the mean pressure against any rectangular lateral area will be on a

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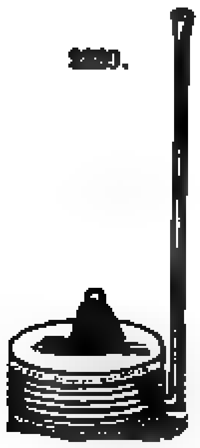

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horizontal line midway between the upper and lower sides of such area. The depth of this line proceeding from the surface of the liquid downward, varies as the odd numbers 1, 3, 5, 7, etc., as will be seen by an inspection of the adjoining diagram, Fig. 2343. The figures placed upon the dotted lines in the centre of the areas indicate the pressures upon those lines, and also the proportional pressures against those areas. The figures on the right side of the diagram indicate the pressures at points of equal vertical distances, while those upon the left indicate the total lateral pressures, which it will be observed are the squares of the number of areas included; by which is demonstrated the second law, that the total lateral pressure against rectangular areas is in proportion to the square of the depth. The weight of a cubic foot of water is 62.5 lbs.; therefore the lateral pressure against a surface of a square foot, whose upper side is in the surface of the liquid, is 31.25 lbs. From this it is easy to ascertain the pressure against a square foot, or any area, at any depth below the surface. Simply multiplying the number of feet below the surface by 2 and subtracting 1, multiplying the remainder by 31.25 and this product by the number of horizontal feet, will give the pressure of a stratum of water a foot deep, at any depth below the surface and of any length. To ascertain the entire pressure against the sides of a vertical cylindrical or prismoidal vessel, square the depth of the liquid in feet or inches, and multiply this by the lateral pressure against an upper vertical square foot or inch, as the case may be, remembering that the weight of a cubic inch of water is .5792 of an ounce, and therefore that the pressure against an upper lateral side is .2896 of an ounce.

Example.—What is the total pressure exerted against the sides of a cylindrical pipe 60 ft. high and 2 in. in diameter? $60^2 \times 31.25 = 112{,}500$. The diameter of the pipe being 2 in., the circumference of the inner surface is 2×3.141592 (the constant ratio) $= 6.283184$ in., or $\frac{6.283184}{12}$ of a foot. Therefore, $112{,}500 \times \frac{6.283184}{12} = 58{,}904.92$ lbs., or 29.45 tons. The lateral pressure on the lower foot would be $(60 \times 2) - 1 = 119 \times 31.25 \times \frac{6.283184}{12} = 1{,}959.64$ lbs., or a little less than one ton.

In the construction of walls for resisting only the hydrostatic pressure of water, as that pressure is in proportion to the depth, the strength of the wall should be in the same proportion. If strength were not given to the lower layers by superincumbent pressure, the inclination of the slope should be 45°; but in consequence of this pressure it may be less, varying with the materials and their manner of being put together. In the construction of dams or barrages the varying circumstances of cases allow of the display of a good deal of engineering skill. A barrage suitable for restraining a body of water which is never strongly moved in a lateral direction against it, as at the outlet of a canal or a reservoir fed by an insignificant stream, would not be adapted to a mountain torrent, where the surface of the reservoir can scarcely ever be large enough to prevent, by the inertia offered by a large mass of water, the walls from being subjected to a strong lateral force from the action of the current. Under such circumstances it is usual to give a curved surface to the facings, in a vertical as well as in a horizontal direction; the curves in both directions being calculated from the following elements: 1, the ascertained hydrostatic pressure; 2, the nature of the materials, such as the weight of stone and tenacity of the hydraulic cement used; and 3, an estimate of the maximum force of flowing water which may at any time be brought against the structure during a freshet. This force, it will readily be seen, will have a different direction and a different point of application in different cases, depending upon the depth and extent of the reservoir. The top of the dam is therefore given a greater horizontal section than would be called for if hydrostatic pressure alone had to be opposed. The hydrostatic pressure at any point against the surface of a containing vessel is the resultant of all the forces collected at that point, and is therefore at right angles to that surface. In a cylindrical or spherical vessel these resultants are in the direction of the radii, and in the sphere vary in direction at every point.

Centre of Pressure.—The centre of pressure is that point in a surface about which all the resultant pressures are balanced. The cases are innumerable, and often require elaborate mathematical investigation. The simplest case and its general application only will be considered here, viz., that of

the centre of pressure against a side of a rectangular vessel. Let any base in the triangle $A\,B\,C$, Fig. 2344, represent the pressure at B; then will $D\,E$ represent the pressure at E, and all lines parallel to it will represent the pressures at corresponding heights. The finding of the centre of pressure now consists in finding the centre of gravity of the triangle $A\,B\,C$, which will be at H, the intersection of the bisecting lines $E\,C$ and $D\,B$, and at one-third the height of the side $A\,B$; consequently the centre of hydrostatic pressure against the rectangular side $A\,B$ is at G, one-third the distance from the bottom to the surface of the liquid. The average intensity of pressure against $A\,B$ being at E, one-half the depth of $A\,B$, therefore the total pressure on the rectangular side $A\,B$ will be the same as if it formed the bottom of the vessel and was pressed upon by a column of water of half the depth of $A\,B$. In general, the total pressure on any surface, plain or curved, is equal to the weight of a liquid column whose base is equal to that surface, and whose height is the distance of the centre of gravity of the surface from the surface of the liquid.

Principle of Archimedes.—A solid immersed in liquid loses an amount of weight equal to that of the liquid it displaces. This is called the principle of Archimedes, and is demonstrated as follows: Let $a\,b$, Fig. 2345, be a solid immersed in a liquid. The vertical section $c\,d$ will be pressed downward by a force equal to the weight of the column of water $e\,c$, and it will be pressed upward by a force equal to that exerted by a column of water equal to $e\,d$; therefore the upward or buoyant pressure exceeds the downward pressure by the weight of a column of water equal to the section $c\,d$. Now, this section also exerts a downward pressure; and if the body is denser than the liquid, the downward pressure will be greater than the excess of the upward pressure of the liquid, and the body will sink if not supported; but if the body is less dense than the liquid, the downward pressure of the column $c\,d$ will be less than the upward pressure exerted against it, and the body will float.

This principle may be experimentally demonstrated by the hydrostatic balance, Fig. 2346. From a balance, b, is suspended a cylindrical vessel, a, from which again is suspended a solid cylinder, c,

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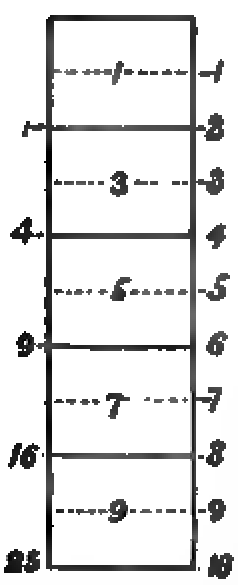

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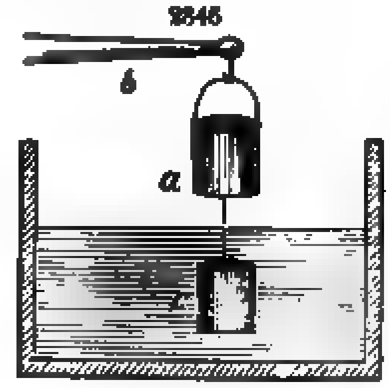

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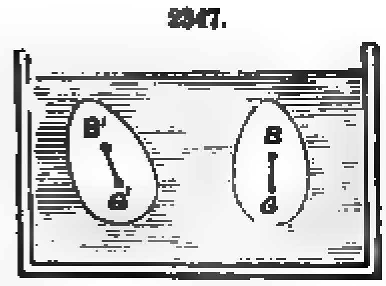

which is of such bulk and dimensions as just to fill the vessel a when introduced. The whole system is first balanced by weights at the other end of the beam, and then c is immersed in water. The equilibrium will be destroyed, and that the body c loses a portion of its weight equal to that of an equal bulk of water is proved by filling the vessel a with water, when the equilibrium of the balance will be restored. It is by means of a similar apparatus that the specific gravities of solids are ascertained (see Gravity, Specific); and upon the principles already laid down hydrometers, or instruments for ascertaining the specific gravity of liquids, are constructed.

Stability of Floating Bodies.—There are certain points to be observed in determining the stability of floating bodies; these are: 1, the centre of gravity of the floating body; 2, the centre of buoyancy; and 3, the metacentre. When a body floats upon water it is acted on by two forces: 1, its own weight, acting vertically downward through its centre of gravity; 2, the resultant force produced by the upward pressure of the liquid, which acts through the centre of gravity of the fluid that is displaced, which point is called the centre of buoyancy of the body. It follows, therefore, that these two points, the centre of gravity and the centre of buoyancy, must be in the same vertical line for the body to be in a state of equilibrium; for otherwise the two forces, one acting downward and the other upward, would form a couple which would cause the body to turn. When these two centres are in the same vertical line, but the centre of gravity is above, the body, except in some cases to be noted presently, is in a state of unstable equilibrium; but when the centre of gravity is beneath, the body is in a state of stable equilibrium. If a body is floating in a liquid and is entirely immersed, it will not come to a state of stable equilibrium until the centre of gravity is vertically below the centre of buoyancy. This is shown in Fig. 2347, in the case of bodies which are less dense at one end than at the other, where B and B' are the centres of buoyancy and G and G' those of gravity.

But in many cases, when a body is only partially immersed, the centre of gravity may be above that of buoyancy, and yet the action of turning cannot take place, so that a condition of stable

equilibrium will be attained under these circumstances. If a flat body, such as a light wooden plank, is placed in water, it will float, and a portion will be above the surface, as shown in Fig. 2348; and therefore, if the centre of gravity is not below the centre of volume, it will be above the centre of buoyancy, and yet the body will be in a state of stable equilibrium. For if it be tipped as represented in Fig. 2349, the centre of buoyancy will be brought to the position B', on the depressed side of the vertical passing through the centre of gravity, and this will cause the body to return to its former position. But if the body has such a shape that when it is displaced the centre of buoyancy is brought to that side of the vertical passing through the centre of gravity, which is elevated as represented in Fig. 2350, then the body will turn over. When the body is in the new position, a vertical drawn through the changed position of the centre of buoyancy will intersect the line which in the first position passed vertically through the centre of gravity, and this point of intersection is called the metacentre, represented at M in Figs. 2350 and 2351. When the metacentre is above the centre of gravity, as in Fig. 2351, the body will tend, by the action of the centre of buoyancy, to return to its former position; but when it is below, as in Fig. 2350, the action of the centre of buoyancy, being upward on the elevated side, will tend to turn the body over. Its proper place, therefore, as its name would indicate, is above the centre of gravity, but it cannot be a fixed point. In all well-built ships, however, its position is pretty nearly constant for all inclinations. For example, in Fig. 2351, as long as increase of inclination of the vessel carried the centre of buoyancy B to the left, the point M might remain at nearly the same distance from G, because it would also move to the left. But if the inclination of the vessel in the same direction carried the centre of buoyancy to the right, the height of the metacentre M would diminish until it would be in G, when the equilibrium would be indifferent, and at last below G, when the ship would turn over. It is desirable to have the metacentre as far as possible above the centre of gravity; and this condition is secured by bringing the centre of gravity to the lowest practicable point, by loading the ship with the heaviest part of the cargo nearest the keel, or by employing ballast.

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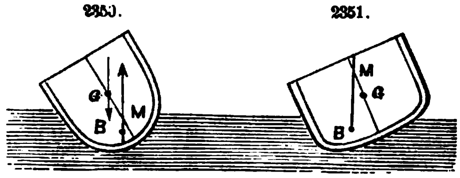
2350. 2351.



ICE-HARVESTING APPARATUS. Ice-cutting, as practiced on the lakes and rivers of this country, is a process essentially American. The season during which ice can be gathered is (at least in the Eastern States) so brief that the utmost activity is required to obtain the supply necessary for home consumption, irrespective of the demands of our large export trade, which in 1876 amounted to over 60,000 tons, representing $200,000 in value. Ice has been a commodity only since 1825. In 1876 the amount required for home consumption and harvested was over 2,000,000 tons, requiring a force of 10,000 men and 4,000 horses.

Harvesting.—When a favorable time comes for gathering the ice, there is a scene of great activity in the vicinity of the storing-houses. A field is laid out varying according to the facilities for gathering. On the Hudson River in New York, and the Kennebec River in Maine, from which immense quantities are taken, the first operation is the removal of any loose snow. This is accomplished by

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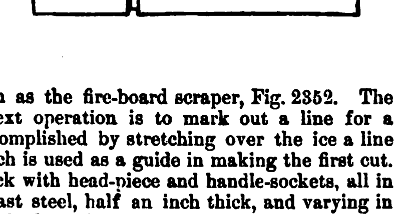

means of the V-shaped plough, and also what is known as the fire-board scraper, Fig. 2352. The snow now being removed and the "field" clear, the next operation is to mark out a line for a machine known as the "marker." This is generally accomplished by stretching over the ice a line half an inch thick and several hundred feet long, which is used as a guide in making the first cut. The marker generally used consists of a wrought-iron back with head-piece and handle-sockets, all in one. Into the back are set eleven cutting teeth of cast steel, half an inch thick, and varying in length from half an inch in the first tooth to 3 inches in the last, clear of the back. Each tooth has 2 inches insertion, and they are secured in position by two wrought-iron bolts. Immediately in front of the first tooth is a small piece of steel a quarter of an inch shorter than the first tooth. Its purpose is to remove loose ice, stones, etc., from the path of the marker. Each tooth cuts a quarter

of an inch, the full depth being 3 inches; the cutting depth can be regulated by the adjustable guide at the heel of the marker. Attached to the back of the marker by a hinge-joint and bolts is the swing-guide, made of cast-steel, designed to regulate the size of the cake to be cut. Each marker has two such guides, of 22 and 32 inches. The guide is steadied by a bar extending to the stiffening-rod of the handle, and also used to raise the guide in case an obstruction is met.

The marker follows with its guide the line first laid out. When the end of the line is reached, the guide is reversed and set to run in the groove just made, and this process is repeated at a distance of 22 inches between each cut until the whole field is marked off in parallel lines.

The Ice Plane, represented in Fig. 2353, is used to cut off snow-ice and dirty ice. It is made of

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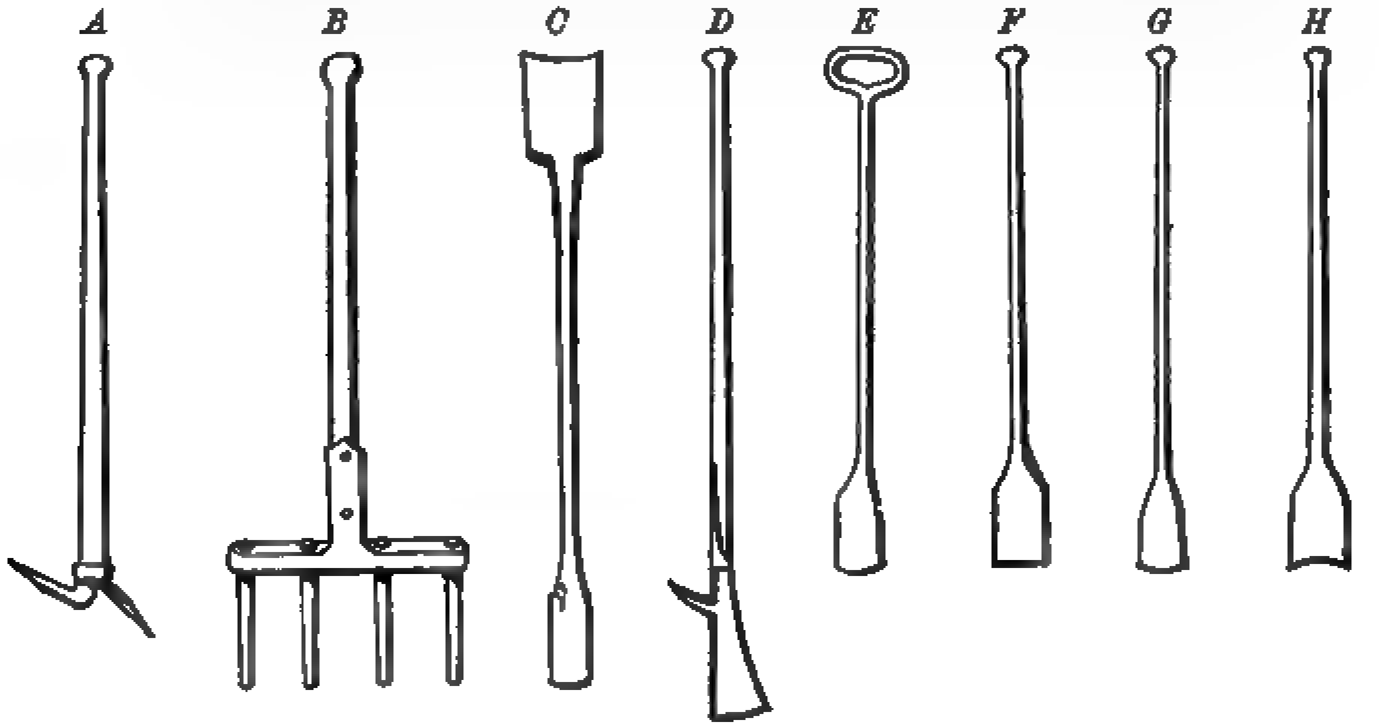
cast-iron, is 22 inches wide, and is quite heavy. After marking the ice to a uniform depth with a marker, the sides of the plane run upon the bottom of these grooves, and the knife can be set to cut off any thickness up to about 3 inches, as desired. The amount cut off is regulated by setting the knife by means of the set-screws on the sides; these should be securely screwed into their seats before using the plane. The weight of the driver keeps the plane steady in the grooves. When the plane has rendered the ice smooth, the marker, with its guide changed to 32 inches, crosses the parallel lines at right angles, and continues until the field is marked off in blocks 22 by 32 inches. The

2357



plough is now used to finish the cutting, which is generally required to be one-half the thickness of the ice, but varies according as the ice is soft or very thick.

Ice-Ploughs.—Ice-ploughs are designed to finish the work begun by the markers, and they are graded to follow each other according to the thickness of the ice to be harvested. The cutting is done by means of a series of teeth, each one of which varies slightly in length from the rest, the shortest being at the front of the row. Each of these teeth will cut about a quarter of an inch of ice, so that a plough with 8 teeth will go through about 2 inches each time it passes along the grooves. Ice-ploughs are made either with or without the swinging or stationary guide, these being required only when the marker is dispensed with. Fig. 2354 represents the form of ice-plough made by the Knickerbocker Ice Company of Philadelphia (to which corporation we are indebted for much information and many of the engravings presented in this article). The implement here depicted is strongly made of cast-

steel. Fig. 2355 shows a hand-plough, used for drawing the first straight line on the ice for the marker or plough to follow. It is also convenient for reopening short grooves which have been frozen, for finishing the ends of grooves, or for marking large blocks intended to be cut into two or more cakes when taken from the ice-house.

After the plough has cut the ice to proper depth, the *ice-saw*, Fig. 2356, is used to open the channel through which the blocks are to pass to the hoisting machine, or to cut them to the desired size. This implement varies in length from 4 to 5 feet. The first row of ice-blocks, after being sawed, are either pushed under or hauled out. Afterward the blocks are separated by the tools represented in Fig. 2357.

Ice Tools.—*A*, Fig. 2357, is the ice-hook, used for storing ice in houses, towing it in the field, or handling it on the platforms or cars. The handle varies from 4 to 16 feet in length. *B* is a fork splitting-bar, for splitting the sheets as they pass along the channels to the elevator. The teeth split the ice evenly, and for this reason this implement is often preferred to the single broad blade. *C* is a grooving-bar, supplied with a broad, blunt blade at one end, which is used to insert in the grooves made by the plough and to break off the ice from the field into sheets; at the opposite end there is a sharp blade like a chisel, which is employed only when the groove has been frozen over. *D* is a

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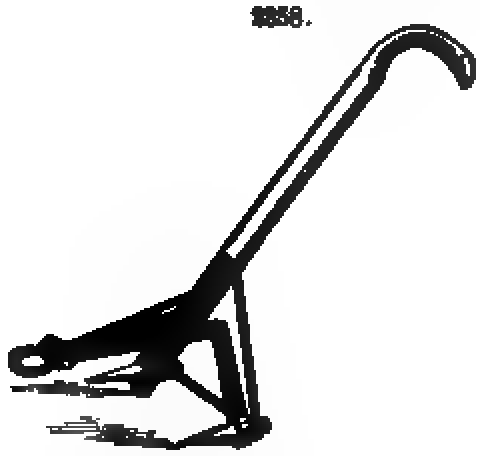

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2360.

channel hook-bar, or chisel and hook combined. This, when attached to a long wooden handle, is very convenient for drawing the ice near enough with the hook to split the sheets and single cakes with the chisel part of the bar. *E* is a splitting-bar, used to split large sheets into single blocks as they are floated along the channels to the ice-house. The ring is desirable, as it prevents the bar from slipping through the hands in wet or very severe weather. *F* is a calking-bar, used for packing the grooves made by the plough at the sides and ends of the sheets, and thus preventing the water from flowing into the grooves and freezing the blocks together again while they are being floated down the channel to the ice-house. *G* is a chisel or raising-bar for separating the cakes; and *H* is another form of splitting-bar used for both separating and splitting the cakes.

Grapples are represented in Figs. 2358 and 2359. These are chiefly used to draw ice up an inclined plane where there is no other elevating machinery for filling ice-houses. That represented in Fig.

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2358 is a much heavier and stronger implement than that shown in Fig 2359, and is generally furnished with a stationary plough-handle.

Elevating and Storing Ice.—Various means are employed for elevating the blocks of ice into the storehouses. Dealers who harvest small crops, ranging from 4,000 to 8,000 tons per season, necessarily use devices of the simplest kind. Tongs, such as are represented in Figs. 2360 and 2361, are

most commonly employed. These are made of well-tempered steel. The form shown in Fig. 2361 is furnished with adjustable joints, with three teeth in the plate, which press firmly against the sides of the ice. Two pairs of tongs can be worked with one horse.

Ice-Gigs or *Platforms*, of the shape shown in Fig. 2362, are often used instead of tongs. The block is easily floated upon the gig, which is then hoisted.

Where large amounts of ice are harvested, elevators of special construction are employed. Of these there are two classes: the ice-screw and the inclined plane or endless chain.

The Ice-Screw Elevator, made by the Knickerbocker Ice Company of Philadelphia, consists of a large helix of wrought-iron wound about a wooden stem. The latter is rotated by spur-gearing, connected by belting with the horse-power. The ice, being floated upon the helix, is caused by the rotation of the latter to ascend and finally to pass off by a chute. By reversing the motion, the ice can be lowered from the building as rapidly as it can be elevated, the weight of the ice furnishing the power. A simple brake is required to prevent the screw from revolving too rapidly, and to stop it when required.

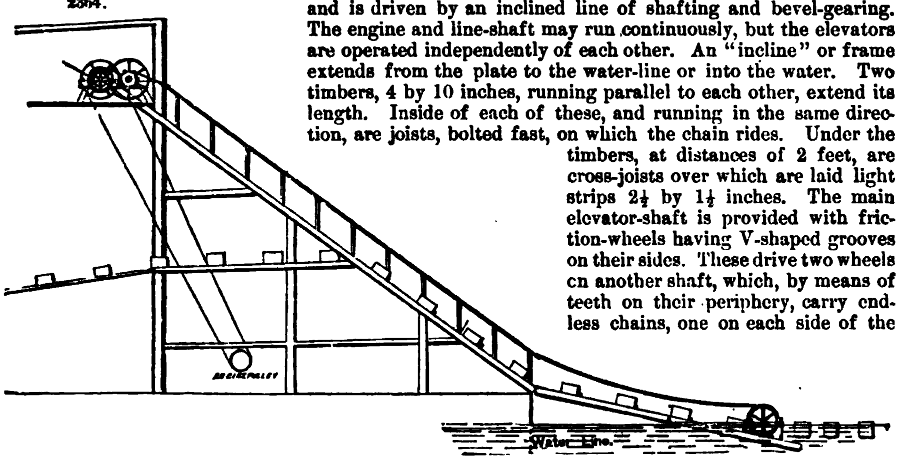
The Endless Chain Elevator is represented in operation in Fig. 2363. The apparatus, as made by the Knickerbocker Ice Company of Philadelphia, consists of an endless chain, which runs along a loading platform to the doorways of the ice-house or series of ice-houses, as the case may be. At intervals on the wharf side of this platform are hoisting-ways, by means of which the ice is taken from the vessel's hold and deposited on the chutes. The latter are elevated so as to give the ice sufficient

motion to carry it gently to its place on the chain, when it is conveyed along the platform, until it reaches the point where wagons are ready to receive it, or is conducted up into the ice-houses, should it be intended for storage. The rear portion of the platform is supplied with a simple adjusting apparatus, by which the runs can be elevated or depressed, as the ice may be wanted at the top of the ice-house or on a level with the platform. When the machine is needed for loading from the house instead of from the vessel, the motion is simply reversed, when the ice is brought down the inclined plane and along the platform to the wagons or cars, as may be required. By the aid of one of these machines, 1,000 tons of ice daily can readily be removed from the vessel to the ice-house, or from the latter to cars or wagons, and with regularity and ease.

Two forms of this device are made, one "overshot" and one "undershot," the latter feeding the ice under the shaft by reversing the motion of the chain. The advantages of this last device are, that the elevator can be used in very shallow water, and can be adapted to any ice-house, to an incline of any grade, and, by putting in an extra pair of water-wheels, to any angle. It also requires less chain than the overshot machine.

The Gifford Elevator, constructed by Gifford Brothers of Hudson, N.Y., is shown in Fig. 2364, which represents a sectional view of the "incline," two chain-wheels, and the friction-gearing at the top of the house. An elevator is used singly for a 5- or 10-ton house, or 8 or 10 of them for 60- and 80-ton houses may be connected by a line of 3½- or 4-inch shafting. The line of shafting is situated 4 or 5 feet above the plate, and about 8 feet from the front of the house, and is driven by an inclined line of shafting and bevel-gearing. The engine and line-shaft may run continuously, but the elevators are operated independently of each other. An "incline" or frame extends from the plate to the water-line or into the water. Two timbers, 4 by 10 inches, running parallel to each other, extend its length. Inside of each of these, and running in the same direction, are joists, bolted fast, on which the chain rides. Under the timbers, at distances of 2 feet, are cross-joists over which are laid light strips 2½ by 1½ inches. The main elevator-shaft is provided with friction-wheels having V-shaped grooves on their sides. These drive two wheels on another shaft, which, by means of teeth on their periphery, carry endless chains, one on each side of the incline. These chains pass down and over two wheels in the water, and are connected by bars of oak (4 by 4) placed 6 feet apart. The bars catch and carry up one or two cakes of ice, which the "feeder" shoves in. The incline is fitted with openings in its framework, at various distances, through which the ice falls upon a "run," on which it slides by its own gravity to the centre of the room where it is "placed." A space of 2 inches is left around each cake. The room being filled to the height of the run, the opening in the incline is closed and the ice is carried to the next opening above, and so on till the house is filled. Should there be any obstruction, the elevator tender lets go the lever, the friction-gears are thrown apart, and, as the pinion turns loosely on the shaft, it fails to drive the chain-wheels, and the chain is stopped instantly, and prevented from slipping by a heavy positive brake acting on the cogs of the chain-wheel. This elevator is claimed to have a capacity for raising two cakes of 24-inch ice per bar, or 720 tons per hour, with a chain-speed of 120 feet a minute.

2364.



Storing-Houses.—The buildings used for the storage of ice are not constructed according to any generally recognized plan. The walls are usually composed of a substance which is a non-conductor of heat. Both brick and wood are used in their construction, each having its advocates. Those who favor brick state that ice keeps best where the walls are double, with intervening dead-air spaces. Those who prefer wood object to brick on the ground that, the outer wall being heated, the air between is also heated, and that practically the greatest waste is in the immediate vicinity of the walls, for a space often of 3 feet on all sides. In building with wood heavy joists are used, sheathed inside and out with 1-inch matched boards, the intervening distance of 12 inches being well packed with saw-dust or spent tan-bark. Sometimes the walls are triple or quadruple. Some houses are built in stories, with sluiceways to carry off the melted ice. These buildings, however, have been found to waste more rapidly than where the entire space between walls is filled with solid ice. The wooden buildings, being the cheaper and more economical, are generally used, and are constructed from 100 to 400 feet front, 100 to 200 feet deep, and 35 to 45 feet high, and divided into rooms 50 by 100 feet, separated by thick partitions, which have an open door from roof to floor, capable of being closed as the room is filled. The capacity can be calculated from the fact that a cake 10 inches thick, measuring 22 by 32 inches, weighs about 250 lbs. The net waste in a room 90 by 60 feet, and 35 feet high, has been found to be 5 feet on top and 3 feet on the south side, the gross weight of ice in the building being about 3,500 tons.

Some of the buildings are fitted with ventilators of various patterns and styles; but experience

shows that the old cupola form is as good as any. The floor is generally the ground upon which the house is built, having a slope of 6 inches from the centre, the drainage being allowed to work its way under the foundation timbers.

The net cost of harvesting on the Hudson River is from 10 to 15 cents per ton. G. H. B.

ICE-MAKING MACHINERY. An economical means of freezing water is a fruitful source of profit, for the manufacture of ice serves not only the purpose of enhancing our bodily comfort in summer, but also for rapidly cooling large volumes of liquid, as in the operation of brewing and other industrial processes, and for the better preservation of animal food in seasons and climates which hasten putrefactive changes. The difficulty experienced in freezing water is due to the very large amount of heat it must lose, first, in being lowered to the temperature of 32° F., and secondly, in being changed from liquid water at 32° F. to solid ice at the same temperature. The first quantity is called its specific heat, and the second is its latent heat. These quantities are greater for water than for any other substance; hence the cooling power of ice is greater for any given temperature than that of any other body, and the cooling power of water is greater than that of any gas or liquid. Faraday calculated that the heat absorbed during the conversion of a cube of solid ice measuring 3 feet in the length of one side into liquid water without undergoing any rise of temperature, would require the combustion of a bushel of coal for its artificial production. It is evident from these statements that, in order to cool a quantity of heated air or water down to a moderate temperature, a large supply of water is the best medium, not only on account of its cheapness and abundance, but because of its great capacity for heat. When any elastic fluid is compressed, it becomes hot, and if it then be cooled down to its original temperature and be expanded, it is rendered as many degrees colder by its rarefaction as it was heated by its condensation; hence we have here a means of producing low temperatures. On the other hand, we can ignite tinder by the heat evolved in the compression of air in a glass cylinder; and by the exhaustion of the air in a bell-jar the temperature may be reduced so that the moisture it contains is deposited as a mist.

By the extremely rapid expansion of a liquefied gas when pressure is removed, or of a volatile liquid when its evaporation is hastened by mechanical means, we obtain the most effective cooling powers. The familiar experiment of freezing water or mercury in a red-hot dish is effected by the enormous expansion of liquefied sulphurous acid or solidified carbonic acid, which substances regain the heat they lost when undergoing the change of liquefaction or solidification. By similar means Messrs. Pictet and Cailletet have succeeded in liquefying and even solidifying the permanent gases. To liquefy oxygen, M. Pictet uses a conical shell containing 700 grammes of chlorate of potash. This shell answers as a retort, and is placed over a gas-furnace or burner. The gas is compressed into a long curved iron tube fitted to the apex of the shell. This tube is placed in a long box on a table, and is terminated by a pressure-gauge; the tube is hermetically closed during the time the gas is being produced; the compression is due, therefore, solely to the effect of the chemical decomposition. The above tube is surrounded by a larger one containing liquid carbonic acid, which, in volatilizing under the action of the suction pumps, produces a cold of −220° F. This liquid carbonic acid is liquefied in a tube contained in a smaller box placed above the first large one. Two compression-pumps take the carbonic acid in a gaseous state from a gasometer, and compress it into the tube contained in the small box. This tube forms a reservoir of liquid carbonic acid, and must be made very cold. It is enveloped by a larger tube containing liquid sulphurous oxide, which is continually vaporized. The liquid sulphurous oxide is constantly provided from a reservoir or condenser, and the duty of two pumps is to exhaust the oxide from around the carbonic acid and compress the oxide again into a liquid state in the condenser. M. Pictet found that oxygen was liquefied at −202° F. (−130° C.) under a tension of 273 atmospheres, when carbonic acid was employed, and at −220° F. (−140° C.) with a tension of 252 atmospheres when nitrous oxide was used. The maximum pressure used during the experiment was 525 atmospheres. For hydrogen, a pressure of 652 atmospheres and a cold of −220° F. were found necessary to liquefy it. In the above experiments the solidification of particles was made apparent by the peculiar sound of the gas as it issued from the tube when the valve was opened, the particles striking the floor with a noise like that of fine hail. The electric light thrown on the jet showed a bright central core of solid matter. Air has also been liquefied by the above process. (See *La Nature*, 1877, 1878; *Journal of the Franklin Institute*, cx., 187, 190, 319; *Scientific American*, xxxviii., 147; *Scientific American Supplement*, v., 1883; *Engineering*, xxv., 324.)

The performances of ice machines indicate remarkable abstractions of heat in proportion to the fuel consumed. The theoretical considerations governing the freezing by expanded air are as follows: The amount of heat to be taken from a pound of water at 60° to reduce it to ice at 32° is 170 units, namely: one pound of water at 60° to ice at 32° involves an abstraction of 28, and between water at 32° to ice at 32° are (latent) 142 units. One pound of air at 1 atmosphere and at 60° compressed to 2 atmospheres is heated 116°; multiplying this by .238 specific heat, we have 27.6 units per pound of air. Hence to freeze a pound of water from 60° requires $(170 \div 27.6 =)$ 6.16 lbs. of air, which is equal to 81 cubic feet of air at 1 atmosphere and at 60°. Now to compress 1 cubic foot of air to 2 atmospheres requires 1,630 foot-pounds. Therefore $1{,}630 \times 81 = 132{,}030$ foot-pounds, or total required to compress 81 cubic feet to 2 atmospheres. The mechanical equivalent of the unit of heat (see DYNAMICS, and EXPANSION OF STEAM AND GASES) is 772 foot-pounds; hence the 170 units necessary to be taken from a pound of water in order to freeze it required 170×772 foot-pounds $= 131{,}240$ foot-pounds, which is very nearly the amount we have calculated. The indicated horse-power being equal to 33,000 foot-pounds per minute, one horse-power therefore would produce $(33{,}000 \times 60 \div 132{,}030 =)$ 15 lbs. of ice per hour. If 33 per cent. be deducted for friction of air-pumps, etc., and allowing 5.75 lbs. of coal per indicated horse-power, we have $(10 \div 5.75 =)$ 1.75 lb. of ice per pound of coal.

In ice machines wherein ether, etc., is evaporated, the proportionate yield far exceeds these figures. In the Siddeley and Mackay machine, which will be found described farther on, the proportion is 1

lb. of coal to 8 lbs. of ice, this having been determined by over 15 months' continuous running. (See *Engineering*, xxiii., 484.)

The reason for the more economical operation of the compressed-air machines is readily seen from the following

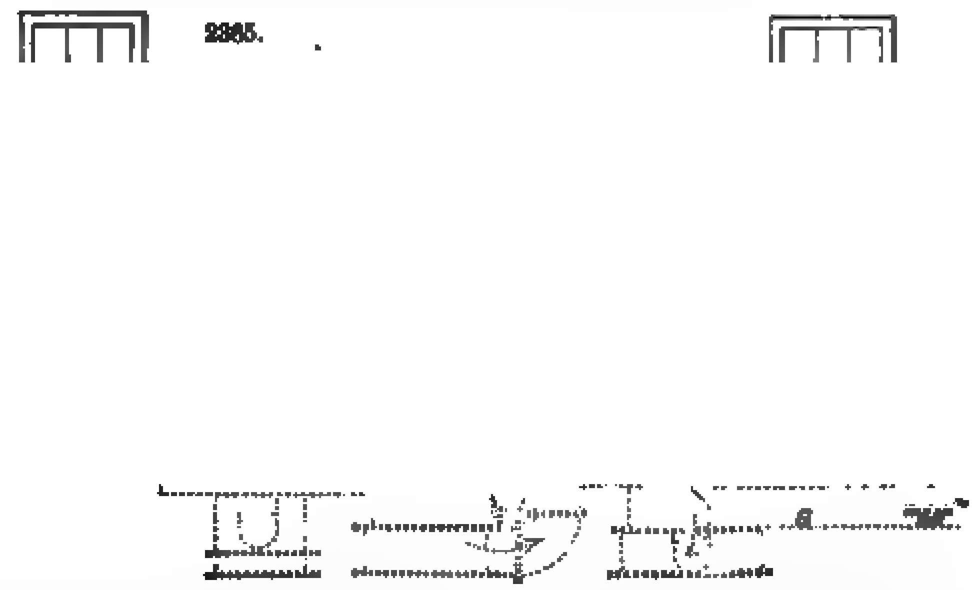
Table of Corresponding Pressures, Boiling-Points, and Volumes of Watery Vapor.

Inches of Mercurial Column in Pressure-Gauge.	Corresponding Pressure in Pounds per Square Inch.	Corresponding Approximate Temperature of Boiling-Point.	Volume of the Vapor compared with the Water.
2	1	1[illegible]4°	20,000
1.5	0.75	95°	30,000
1.14	0.57	86°	40,000
[illegible]	[illegible]	77°	50,000
0.64	0.32	68°	60,000
0.48	0.24	59°	80,000
0.36	0.18	50°	110,000
0.26	0.13	41°	160,000
0.186	[illegible]	32°	220,000
0.125	0.0625	23°	320,000

From this it appears that as the pressure and temperature decrease the volume of the vapor enormously increases, so that, at the freezing-point of water under a pressure of nearly one-tenth of a pound per square inch, the expansion of the watery vapor is more than 200,000 times the bulk of the liquid. Consequently very active measures are needed to dispose of this vapor, which otherwise would accumulate and by its pressure soon end all further evaporation and subsequent cooling. Hence the disadvantage of the vacuum-pumps acting alone, and the necessity of removing this vapor by extraneous aid. Air machines also require large cylinders and air-tight close-fitting pistons, besides accurate fitting in the various valves. On the other hand, they have the advantage of requiring no aid from chemical agents, of acting directly upon the air and water, and of producing cold air, refrigerating fluids, or making ice continuously, as wished, with the aid of fuel alone. Perhaps the air machine is the one best suited for the artificial refrigeration of air apart from ice-making, inasmuch as the requisite amount of cold can be regulated with the greatest nicety by means of a valve under the control of the attendant.

AIR MACHINES.—The principal types are as follows: In the Windhausen, Fig. 2365, *A* is the compression and *B* the expansion cylinder, both of which are worked simultaneously from the low-pressure engine shown at the lower portion of the figure. Air first enters the cylinder *A* from above,

2365.



passes to the condenser *D*, from which in the direction of the arrow it passes to a similar receptacle *E*, thence down as indicated by dotted lines to another cooler *F*. Within these chambers are arranged series of pipes through which the blast passes, and which are surrounded by a current of cold water that enters at *G* (dotted lines, Fig. 2365), passes up through the cooler *F*, through the pipe *H*, through the next cooler, and emerges at *I*. The effect of this water is to abstract a portion of the heat imparted by compression, reducing the temperature of the air heated by compression to a few degrees above that of its natural state, the extent of this reduction depending upon the temperature of the water and the length of time the air is submitted to its action. In this condition the air enters the cylinder *B*, where the expansion takes place under gradually diminishing pressure regulated by automatic valves worked by the expansive force of the air itself. From the cylinder *B* the air escapes into the space to be refrigerated. The refrigerator used consists of a double-cased rectangular wooden chamber, the space between the casings being filled with loose cotton or other non-conductor of heat. In this, through apertures in the cover, metallic cases containing the water to be frozen are inserted; and to insure the air coming in contact with all parts of these cases, zigzag partitions are placed in the compartments between them.

Kirk's apparatus is adapted for cooling liquids without making ice. The water which removes the heat caused by compression, and that to be cooled, are injected as a shower through the compressed and expanded air of the hot and cold chambers, and are withdrawn by simple valves. When driven wi.h compound engines, a surface-condenser is attached, which enables clear water for divers purposes to be warmed by the exhaust steam. In Mignot's machine the water is injected in the form of spray into the very midst of the air as it is being compressed in the compressing cylinder. The cold air produced, being about 60° below the freezing-point, is conveyed through a trough with large cells containing the water to be congealed, and escapes at about 4° above the freezing-point. The injecting of the spray diminishes the work to be done in compressing the air. In Gorrie's apparatus water is injected on that side of the compressing-piston at which condensation is taking place. The condensed air passes through a worm surrounded by cold water to a reservoir, whence it is admitted to an auxiliary pump driven by the expansion of the compressed air in which it is expanded, cooling a non-congealable fluid in a jacket surrounding the pump-cylinder. This abstracts the heat from the water contained in a reservoir in a chamber above the pump, causing its congelation.

Fig. 2366 represents M. E. Carré's apparatus for freezing water in caraffes for table use. It consists of a comparatively large air-pump *A*, but not too large for being worked by one man; the lever attached to the handle is much longer than is represented here. The horizontal cylinder *B* below contains sulphuric acid, or some other hygroscopic substance (for instance, solid chloride of calcium), which will absorb watery vapor. The bottles in which the water is frozen are made of heavy glass, strong enough not to collapse by atmospheric pressure when the vacuum is made inside. They are attached by an air-tight India-rubber collar or ring to a tube connected with the vessel containing the sulphuric acid or its equivalent, while another part of this vessel is connected by means of a bent tube with the bottom of the air-pump. It is seen that the vapors arising from the water must first pass over the sulphuric acid in the lower horizontal cylinder before arriving at the air-pump, to be expelled by the latter. The bottles are filled with cold water, as seen at the left, and, being attached to the machine as shown, and the pump worked rapidly and with strokes of the fullest possible length, it is found that after the water has boiled from the beginning of the operation, after 50 or 60 strokes, or a time of scarcely one minute, about one-fourth of it will have evaporated, and the remaining three-fourths will suddenly freeze.

Ether Machines.—Under this heading may be classed all those machines in which the cold is produced by the evaporation of a volatile liquid, to effect which there is no direct application of heat. They therefore include the apparatus which employs methylic or sulphuric ether, gasoline, chymogene, and other derivatives of petroleum, methylic oxide, and trimethyline. The tension of ether vapor is weak. At 27° of cold it is but a trifle above a vacuum, 2 or 3 lbs., and hence the evaporation is carried on *in vacuo* by the aid of pumps of large capacity. The obstacles encountered are the tendency of the ether to acidify, the danger of conflagration of the inflammable vapor, and the difficulty of preventing entrance of air to the working cylinder. The ether may be re-used if the stuffing-boxes are kept in perfect order. A large number of machines of this class are in use, in many of which the difficulties above noted are greatly reduced. One of the best examples is *Messrs. Siddeley and Mackay's machine*, where the working fluid is sulphuric ether. This is vaporized in a partial vacuum and absorbs heat from brine during its vaporization. The vapor thus produced is subsequently compressed and delivered into a condenser, where it is liquefied, to be again subsequently vaporized, and so on through a continuous cycle of operations. The power which is used to produce the circulation of the ether and the brine through the apparatus is derived from a Galloway boiler 6 ft. 6 in. in diameter by 22 ft. long. The steam is supplied at 55 lbs. pressure to a pair of horizontal compound engines, having respectively a high-pressure cylinder of 18 in. diameter and a low-pressure cylinder of 28 in. diameter, the stroke in both cases being 3 ft. 3 in. The engine air-pump is driven off the crank-shaft by means of a small vibrating beam at the end of the high-pressure engine bed, and is vertical. The ether vacuum-pumps are horizontal, and worked direct from the piston-rods of the steam-cylinders; they are of 34 in. diameter by 3 ft. 3 in. stroke. Two water-circulating pumps are provided for the pumping of the brine and the fresh water through the various portions of the establishment, and are driven by the same pair of engines, as shown in Fig. 2367. *A* is the high-pressure cylinder, *B* the low-pressure cylinder, *C C* the two ether-vacuum pumps, *D D* the water-circulating pumps, *E* the feed-pump for boiler, *F* the engine air-pump, *G* the engine condenser, *h h* the governors, and *l* and *k* pipes connecting the vacuum-pumps with the ether-condensers.

In dealing with the cycle of operations of which we have sketched the outline above, we will commence with the liquid ether as it is in contact with the brine-cooling surfaces from which it has to absorb heat. The brine-cooling apparatus is a vessel like an ordinary surface-condenser traversed by tubes, which are charged with strong brine. The ether which is in contact with the exterior of the tubes is here vaporized under a vacuum of about 23½ in. of mercury, and at a temperature of 21°, the vapor being drawn off by the ether-pump, which then compresses and delivers it to the ether condenser at a pressure of about 3 lbs. per square inch and temperature of 110°. The ether vapor

however, does not pass direct from the brine-refrigerator into the ether-pump, but is on its way to the latter first caused to pass through a tubular vessel in which is contained the liquefied ether on its return journey for re-use. The vaporized ether here absorbs some of the heat contained in this returning liquid ether, and becomes somewhat warmer in consequence, and passing onward it finally

flows into the vacuum-pump, not at 21° as it left the brine, but warmed to 45°. The compression it receives by the vacuum-piston as it is driven out of the pump raises the temperature to 110°, as already mentioned. The ether vapor, discharged from the pump at 3 lbs. pressure and 110° temperature, passes through a surface-condenser formed of small horizontal copper tubes fixed into metal tube-plate chambers at each end, round about which tubes is a constant stream of water, flowing in at the bottom and out at the top of the chamber. This water enters at the natural temperature of the supply, 62°, and passes off warmed to 74° by heat absorbed from the ether vapor within the tubes. The warmed water is pumped up to a tank elevated to the highest part of the building, from whence it is allowed to descend in contact with the surrounding atmosphere, by which means it becomes cooled ready for re-use. Returning for a while to the ether, which is sent back to the first vessel or brine-refrigerator, it must be explained that another important apparatus intervenes between the inflowing supply of liquid ether, which is at a pressure of 3 lbs. per square inch, and the refrigerator from which it is to pass under the vacuum of 23 in. to the pump. This is the governor, consisting of a small vessel containing an inverted valve attached to a lever and balance-weight, and a ball-float. The adjustments of this governor are such that, as the vessel becomes filled with the returning supply of ether, the valve becomes depressed by the weight of the supply, and some portion of the fluid is permitted to pass away to the refrigerator, but only so much as allows the valve again to close, and maintain the relative differences of pressure unimpaired. We must now follow the course of the brine, cooled to a temperature of 21°, which has been prepared as we have described, and which, having been thus cooled, is ready for the purpose for which it has been formed, viz., the production of pure and clear ice for commerce. The water to be frozen passes into a series of tanks formed of wrought- and cast-iron water-spaces or walls, about 3 in. thick and about 4 ft. deep, placed vertically, and connected at the ends and in the centre of their length in such a manner as to form a number of cells about 3 ft. 6 in. long, 4 ft. deep, and 12 in. wide, the bottom being somewhat narrower than the top to facilitate the removal of the slab of ice when frozen. There are three rows of these tanks, each row being subdivided into six main divisions containing twenty-four cells. When it is desired that the process of freezing shall begin, the cold brine is caused to pass

first of all through the walls of a tank containing cells of cold water. These cells of water in due course become frozen throughout by the continual flow of cold brine at an initial temperature of 21° through the 8-in. water-space walls. In regular and constant work, however, the arrangement differs somewhat, for it is desirable that the currents of cooling fluid and of water to be cooled shall circulate in opposite directions. Therefore in practice the brine of 21° temperature is passed through a tank of ice that is approaching its completion in the process of freezing, and then having been warmed by this duty to say 24°, it is passed on to tank No. 2, whence it passes on to tank No. 3 at say 28°, and finally out from No. 4 at 33°. The water supplied to No. 4 thus is the first to become congealed in regular course, and forms the outer shell of the future block. After a period of say 12 hours, the flow of brine is changed, and that of a cooler temperature, viz., 24° (to be raised to 28° by its duty), is made to flow round this tank in place of that which had been circulating, and again in another 12 hours the next change is made, and brine of about 22° (about to be raised to 24°) is made to flow round the same tank; and a final flow of fresh brine from the refrigerator at the greatest degree of cold finishes off the block and leaves it at that temperature or thereabouts. Thus no very sudden changes of temperature are brought to bear upon any portion of the structure, and both economy of result and duration of parts are insured. The consumption of fuel keeps at about the same rate as at the time of trial, viz., about 20 cwt. of coal for the production of 8 tons of ice. The daily (24 hours) produce is from 22 to 23 tons. (See *Engineering*, xxiii., 599.)

The Siebe and West machine consists of refrigerator, condenser, air-pump, and ice-making box. When the air-pump is set in motion, the ether in the cooling vessel evaporates, and of course absorbs heat from the tubes by which the cooling vessel is traversed. The ether vapor thus produced is forced by the air-pump into the condenser, where, under the combined influence of the pressure and the cooling action of the water circulating through the condenser, it resumes the liquid form and returns through a small tube to the refrigerator, where it is again changed to gas. The process is continued with the use of the same ether as long as the machine is kept working. The great cold produced in the cooling vessel acts on the fresh water to be frozen in the ice-box by means of a current of salt water introduced into the tubes which pass through. The temperature of the salt water decreases quickly on its way through the refrigerator, on account of the heat being absorbed from it by the ether changing into gas, and it then circulates, with a temperature considerably below the freezing-point in the ice-box, round a number of iron or copper vessels filled with fresh water to be frozen into ice. The salt water, the temperature of which increases again by coming into contact with the vessels containing the fresh water, is sent back to the refrigerator, where its temperature is again reduced.

In *Johnston and Whitelaw's machine*, bisulphide of carbon after being vaporized is, with the air forced in by the air-pump, conducted through chambers containing oil, which absorbs the greater part of the moisture of the gas, the moisture of the air being taken up by chloride of calcium in a pipe leading to the air-pump. In *Vander Weyde's machine*, naphtha, gasoline, rhigolene, or chymogene is evaporated by an air-pump and forced through a freezer in which are vessels containing water, surrounded by inclosing vessels filled with glycerine, the outside being surrounded by cryogene. The evaporation of the cryogene causes the freezing of the water. Chymogene, like ether, has a very weak tension at a comparatively high temperature, the point of ebullition being as high as 40° F. It requires large pump capacity and a high vacuum, and it is open to the objection of inflammability. The same difficulties attend the use of methyline, the boiling point of which varies from 37.4° to 53.6° F., according to the impurities and secondary products mixed with the material. Most metals are attacked by methyl-ammoniacal products, and iron must be exclusively used. The properties of methylic oxide are analogous to those of methylic ether; that is, it gives very high pressures at 68° F., at least from 8 to 12 atmospheres.

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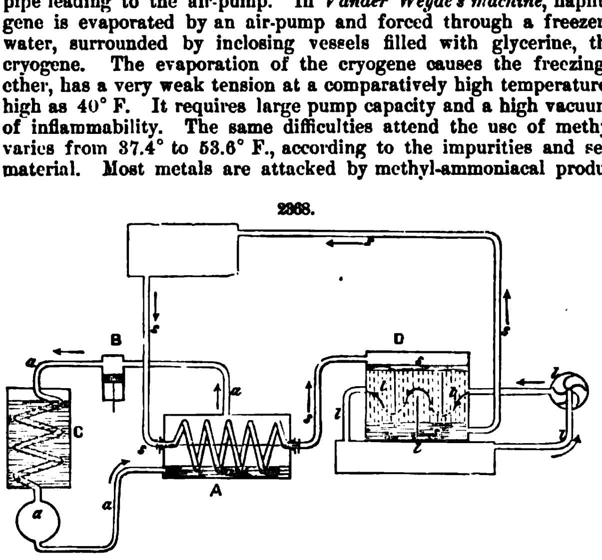

Holden's machine is adapted to the use of chymogene, gasoline, or other easily volatilized liquid. Its operation will be understood from Fig. 2368. *A* is the refrigerator-cylinder, in which is a coiled pipe through which a non-congealable liquid *s* circulates. Inside the cylinder which rotates is the volatile liquid *a*, which is evaporated from the pipe-surface by the aid of the pump *B*, which transmits it to the condenser *C*, where it is reliquefied and sent back to the cylinder *A*. The non-congealable liquid goes to a distributing pan *D*, through which it falls in fine jets, and is traversed by an air-blast *l*, which is thus cooled. The circulation of the air, cold liquid, and volatile liquid currents will readily be understood from the figure

The Pictet System.—The principle of the system of refrigerating machinery devised by M. Raoul Pictet is the volatilization of anhydrous sulphurous oxide, a colorless liquid, having a specific gravity of 1.6, and remaining fluid under a pressure of from 2 to 3 atmospheres. When allowed to escape in air it vaporizes rapidly, producing a decrease of temperature of 135° F.; and if a teaspoonful of the liquid be poured into a wine-glass of boiling water, the latter instantly freezes solid. The point of

ebullition of the oxide is 14° F., under the atmospheric pressure. The whole apparatus is extremely simple, as is indicated by the annexed diagram of a small machine, Fig. 2369. The refrigerator *D* consists of a tubular copper cylinder placed horizontally in a tank through which an uncongealable liquid (solution of glycerine, chloride of magnesium, or various salts) is circulated by means of a

2369.

small propeller-wheel. The moulds or cans *H*, for making the ice, may either be placed in the refrigerator-tank, or in a separate tank specially prepared. The sulphurous oxide is volatilized in the refrigerator *D* by a pump *A*, which sucks the oxide from the refrigerator through the tube *B* (producing intense cold, which is communicated to the surrounding liquid), and then forces the vapor through the tube *C* into the condenser. The condenser *E* is a tubular copper cylinder similar to the refrigerator; a current of cold water is kept constantly flowing through its tubes, which abstracts the heat from the vapor and brings it back to a liquid form. A tube returns the liquid sulphurous oxide to the refrigerator to be revolatilized, while a stop-cock *F* regulates the supply. The pump *A* used is double-acting, and of iron. The piston is of metal, without packing. Its action is very easy owing to the lubricating nature of the oxide. The pump may be driven either direct by an engine or by a belt from shafting.

The large plants for making ice are in principle the same as the small one described above, but with certain alterations of the apparatus on account of the size. The refrigerator, a plain copper tubular boiler, is immersed horizontally in a tank, and is charged with 1,760 lbs. of anhydrous sulphurous oxide once for all. (The oxide comes in copper bottles containing about 200 lbs. each.) Through this tank a mixture of glycerine and water is made to circulate by means of a rotary pump. The solution of chloride of magnesium gives equally as good results as glycerine and water, is less expensive, and as it barely freezes at —25° F. (57° below the freezing of water), an intense cold may be obtained for special purposes. The moulds or cans of galvanized iron, containing the water to be congealed, are placed in a large tank communicating with the small tank holding the refrigerator. The sulphurous oxide is vaporized in the refrigerator, and the vapors generated are aspirated by a double-acting aspiration and compression pump. This pump is a plain cast-iron cylinder, fitted with inlet and outlet valves, and jacketed with a circulation of water. The piston is hollow, and the piston-rod, which is also hollow, is cooled by a circulation of water. The cold produced by the volatilizing of the oxide in the refrigerant is transmitted to the liquid surrounding and passing through the tubes of the latter. This liquid flows by its own weight into the large tank, communicating its cold to the water in the cans, which freezes to ice.

The oxide vapors, entering the pump from the refrigerator at a vacuum of about half a pound to 2 lbs., are compressed to about one-fifth of their original volume, the temperature rising to nearly 200°. The pressure at which the oxide is compressed is usually, in New York, 2¼ atmospheres (35 lbs.), and in the hottest climates does not exceed 4½ atmospheres (68 lbs.). The oxide is returned under pressure to the condenser, placed in an upright iron tank to the rear of the compression-pump. The cold water freely circulating through this tank cools the oxide and carries away the heat. The liquid oxide returns to the refrigerator by two long narrow pipes, the admission being regulated by stop-cocks, and is vaporized anew. The operation is thus perfectly continuous. Under the low pressure employed no difficulty as to leaks occurs, it being easy to keep all the joints tight. No air can enter the oxide-pump, the pressure of the oxide as it enters being nearly that of the atmosphere or a trifle below it. The loss of oxide does not exceed half a pound per week. The solution in the tank very rarely needs renewal or additional material, and is always cheap.

Mr. L. F. Beckwith, engineer of the Pictet Ice Company, furnishes the following data as to the

theoretical and practical considerations governing the working of the machine: "The heat absorbed by the water passing through the condenser, and carried off by this water, is equal to the latent heat abandoned by the sulphurous oxide in passing from a gaseous to a liquid state, added to the heat given to the sulphurous oxide by the work of compression of the pump. The latent heat absorbed by the oxide from the freezing mixture has been obtained by the latter from the water in the cans during the volatilizing of the oxide in the refrigerant. The heat given to the oxide by compression is the equivalent of the work produced by the steam-engine, less that absorbed by friction and the running of the other parts of the machinery. As an example, if the engine indicates 76 lbs., we have, deducting power required to run air-pump, condenser, feed-pump, circulating-pump, hoisting-gear, friction, etc. (25 per cent.), $\frac{33000 \times 60 \text{ min.} \times 57 \text{ lbs.}}{772} = 146{,}194$ units of heat per hour, equivalent to the work produced by the engine in compressing the oxide. Now, to produce ice from water put into the cans at 78° F., it is necessary to withdraw from each pound $(46 + 142 =)$ 188 units of heat; and if 1,500 lbs. are made per hour, the amount withdrawn is $(1{,}500 \times 188 =)$ 282,000 units of heat. The water of condensation passing through the tubes of the oxide-condensers is increased in temperature from 6° to 7° F.; about 1,100 lbs. of water passes through per minute; therefore, with an average of 6½° F., $(1{,}100 \times 6\frac{1}{2} \times 60 \text{ min.} =)$ 429,000 units of heat are carried off per hour. This amount approximates closely to the sum of the heat produced by the work of compression of the engine and the latent heat given up by the oxide in liquefying, and which it had taken from the water through the medium of the cooling mixture of glycerine and water, viz.: $146{,}194 + 282{,}000 = 428{,}194$ units of heat. The amount of coal used per pound per hour is 2.6 lbs. We have then, for coal used in work of compression of oxide and production of ice, 57×2.6, or 148 lbs. for 1,500 lbs. of ice, or 208 lbs. for 2,000 lbs. of ice; the coal at $4 per ton amounts to 41½ cents. Commercially, 76 lbs. being used for running all the machinery, we have $2.6 \text{ lbs.} \times 76 \text{ lbs.} = 204$ lbs. for 1,500 lbs. of ice, or 272 lbs. for 2,000 lbs. of ice; the coal at $4 per ton amounts to 54 cents."

AMMONIA MACHINES differ entirely from those previously described, in which ether, etc., is used, in that no pumps are used or other direct application of power is made to restore the gaseous material to a liquid form by production of pressure. Either a saturated solution of ammonia or the liquefied ammonia is used. The first are necessarily worked under a high pressure. In hot climates, with the thermometer at 95°, the pressure reaches 300 lbs. per square inch, and it is never less than from 180 to 225 lbs. In liquefied ammonia machines the pressure is from 135 to 180 lbs. The difficulties are chiefly the frequent and heavy leaks, the corrosive action of the ammonia on metals, the impossibility of using grease as a lubricant, and the deposits which form in the boilers.

Vaas and Littmann's machine is represented in Fig. 2370. This consists of the boiler *A*, condenser *B*, gas-holder *C*, ice-box *D*, absorption-cylinder *E*, temperature-exchanger *F*, cooler *G*, and pump *H*.

The boiler *A* is first half filled with solution of ammonia, which is caused to evaporate by the application of heat, and the gas thus formed is forced through the pipe *I* into the worm-pipe of the condenser *B*, and thence through the pipe 2 into the gas-holder *C*. From the gas-holder the gas is conducted by the pipe 3 to the valve on the top of the ice-box *D*, which is in connection with the worm-pipe inside the ice-box. The gas on its passage through the worm-pipes of the condenser (which are always surrounded by cold water) is condensed, and the liquid passes through the valve to the worm-pipes in

the ice-box, where it again begins to evaporate, taking up at the same time heat from the solution of chloride of calcium, in which the worm-pipes in the ice-box are submerged. This absorption of heat so lowers the temperature of the solution of chloride of calcium as to render it capable of turning the fresh water contained in the ice-cases to ice. The ammonia which has been volatilized in the pipes of the ice-box passes through the pipes 4 to the absorption-cylinder *E*, and at the same time the weak solution of ammonia, which has lost the gas by heat, passes out of the boiler by the pipe 5 into the exchanger *F*, through the cooler *G*, into the absorption-cylinder *E*, where it absorbs the gas which comes from the ice-box; and from these it is pumped back by the pump 7 into the boiler to be again heated. A machine of this kind for making 200 lbs. of ice per hour is stated to require a 2-horse-power engine to drive it.

The Atlas machine, Fig. 2371, has a still *A*, lime-drier *B*, condenser and tank *C*, and refrigerating tank *D*. The still incloses a coil of pipe, which is covered by the liquid ammonia. The gas arising passes through the lime-drier, which is simply a cast-iron cylinder containing unslacked lime, and

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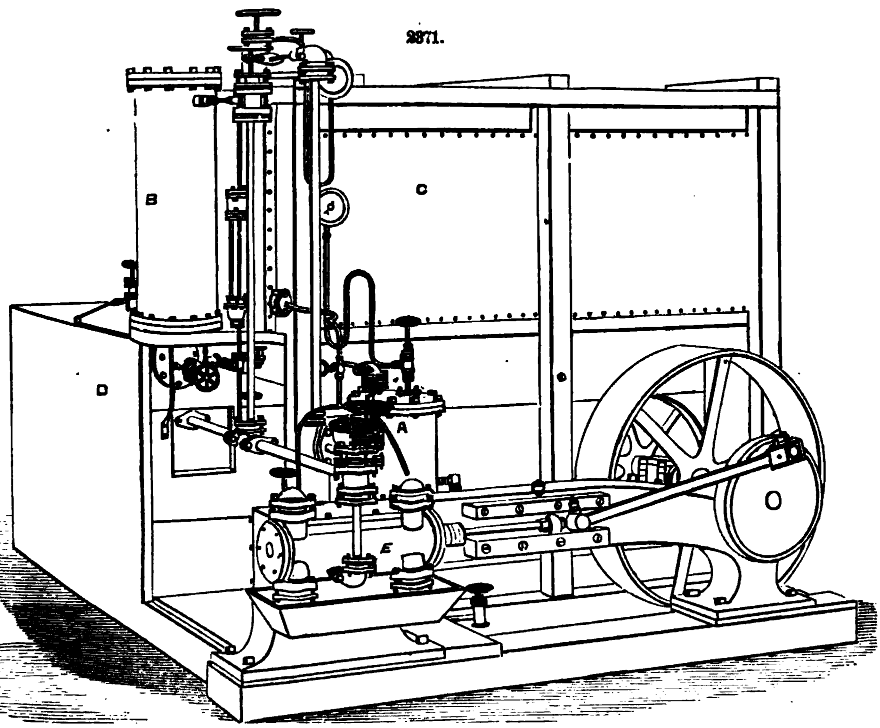

thence goes to the pumps *E*, whence it passes to the condenser contained in the tank *C*, where it is liquefied by pressure. The ammonia stored in the condenser is conveyed through a pipe to a distributing manifold, inclosed in the refrigerating tank *D*.

In *Reece's machine*, a generating vessel is charged with a solution of ammonia, and a fire is lighted under the boiler, which expels all the air. A strong solution of ammonia is then pumped to the top of an analyzing cylinder above, and as the solution descends the different plates there it is in a great measure separated from the water by the steam. The ammonia next goes to a rectifier, where it is cooled by a stream of cold water, and rendered perfectly free from watery vapor. It then passes to a liquefactor, where it is liquefied by the mere pressure of the gas itself; it next proceeds to a cooling-cylinder, and then to a second cylinder, where it resumes the gaseous state, cooling the liquid inclosed in the coil. The now exhausted ammonia passes to an absorbing vessel, where it meets with the exhausted liquor from the generator and is dissolved. The solution is now pumped through a horizontal heater, where it meets with the liquor proceeding from the boiler into the top of the analyzing-cylinder, where the same series of operations is repeated.

M. Ferdinand Carré's ammonia machine is represented in Fig. 2372. *A* is a boiler, which contains an aqueous solution of ammonia. This boiler is heated by steam led by the tube *C* into the coil *B*, the water of condensation of which escapes in the condenser *D*. The solution being heated by the steam, the gas passes by the tube *K* into the liquefier *L L*. This consists of a tank containing coils, around which circulates a continuous current of cold water, which descends from the reservoir *Z* by the tube *h*. The liquefied ammonia passes through a tube which is itself contained in the sleeve *P*, and goes to the cooler *M*. In this receptacle the ammonia liquid, which is contained in a coil *P*, is again gasefied. The water to be frozen is placed in long cylinders *R*, which are plunged in a non-congealable liquid, a solution of chloride of calcium. The cylinders with their frozen contents are removed about every fifteen minutes. The ammoniacal gas, disengaged from the liquid as it passes

through the cooler-coil, passes through the tube S to the absorption-chamber T, following the tube e. In this chamber is a coil surrounded by cold water, and in the coil the gas resumes a liquid condition. The liquid is then pumped back into the boiler A.

From experiments made by Dr. R. Schmidt of Berlin in 1870, on both the Carré ammonia and the Windhausen compressed-air machines, the following results were obtained: Experiments were made during 150 days, 12 hours being estimated to the day; and for each horse-power 96 lbs. of coal were taken. There were also consumed 110 lbs. of sal-ammoniac and 110 lbs. of chloride of calcium. The results were, that a Carré machine produced hourly 400 lbs. of ice at 1½ cent per pound; the running expenses of the Windhausen machine were one-third higher, and the cost of the ice nearly 2 cents a pound.

From tests made as to the economy of producing cold dry air by artificial refrigeration, instead of the damp air obtained by melting ice, in which a Carré apparatus capable of producing 5 lbs. of ice per minute was used, the following result among others was reached: It was found that 300 lbs. of natural ice were required to reduce the temperature of a room from 80° to 46° F. in 2 hours and 20 minutes, which effect was obtained by Carré's apparatus in 7 minutes with the same quantity of cold required to form 35 lbs. of ice; thereby showing that 6 times as much ice was consumed to produce the same quantity of cold air as was supplied by the apparatus.

Machines based on the Use of Freezing Mixtures.—Freezing mixtures are combinations of chemicals which in dissolving in water absorb large quantities of heat, and so cause notable diminutions of temperature. The following are well-known mixtures: 1. Salt 1 part, cracked ice 1 part; temperature obtained, from 50° to 10.4° F. 2. Water 10 parts, muriate of ammonia 5 parts, saltpetre 7 parts; temperature obtained, from 50° to 3.4° F. 3. Water 1 part, muriate of ammonia 1 part; temperature obtained, from 50° to 14° F. 4. Sulphate of soda 8 parts, hydrochloric acid 5 parts; temperature obtained, from 64.4° to 1.4° F. The use of acids is always disagreeable and dangerous, and hence it is preferable to employ nitrate or hydrochlorate of ammonia.

Proportions of various Chemicals to be added to four parts of Water to produce Temperatures noted.

	Lowering of Temperature, in Degrees Centigrade.		Lowering of Temperature, in Degrees Centigrade.
4 parts nitrate of ammonia	20°	1 part chloride of potassium	11.8
1 part " "	14.1	1 " sulphate of soda	8.0
5 parts nitrate of ammonia and 5 of saltpetre,	22.0	1 " chloride of sodium	2.1
1 part nitrate of ammonia	15.2	1 " nitrate of soda	9.4
1 " sulphate of potash	2.9	1 " acetate of soda	10.6

If, instead of water at normal temperature, ice or snow is employed, still further abstraction of heat is secured. The greatest attainable lowering of temperature by the aid of a saline mixture is the degree at which the solution itself congeals This is shown in the following table, the chemicals noted being mixed with 100 parts of snow:

	Temperature obtained, in Degrees Centigrade.		Temperature obtained, in Degrees Centigrade.
10 parts sulphate of potash	− 1.9°	25 parts hydrochlorate of ammonia	−15.4
20 " carbonate of soda	− 2.0	45 " nitrate of ammonia	−16.75
13 " nitrate of potash	− 3.85	50 " nitrate of soda	−17.75
30 " chloride of potassium	−10.9	33 " chloride of sodium	−21.3

Sulphuric acid diluted with water and mixed with ice gives very intense cold. Mingled with 25 per cent. of its weight of water and 33 per cent. of its weight of ice or snow, it produces a refrigeration of −32° C., and with equal parts of acid and snow of −44° C.

A simple device for producing ice in small quantities by means of freezing powders has been invented by M. Toselli of Paris, and is illustrated in Figs. 2373, 2374, and 2375. It consists of a cylin-

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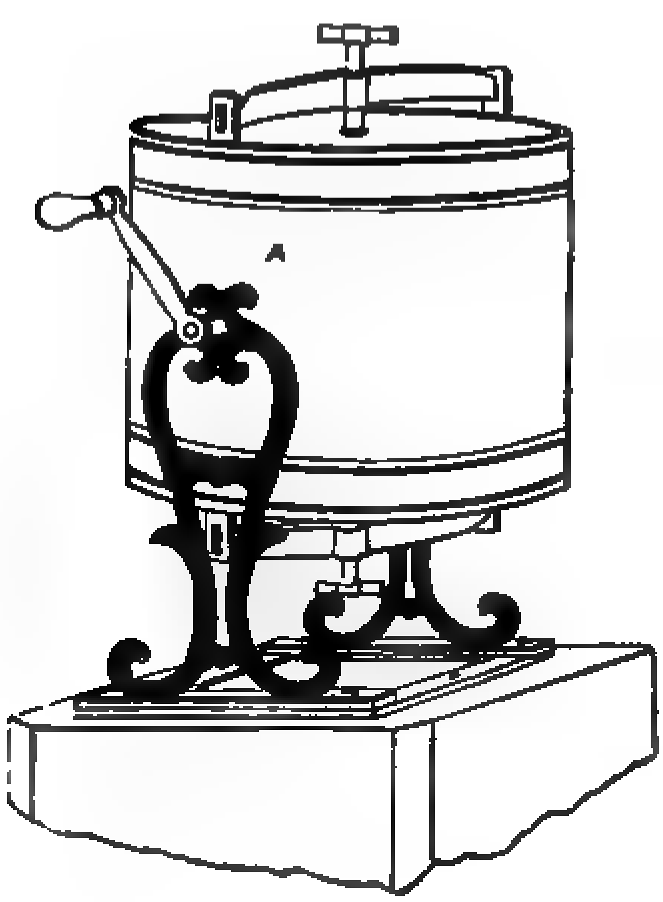

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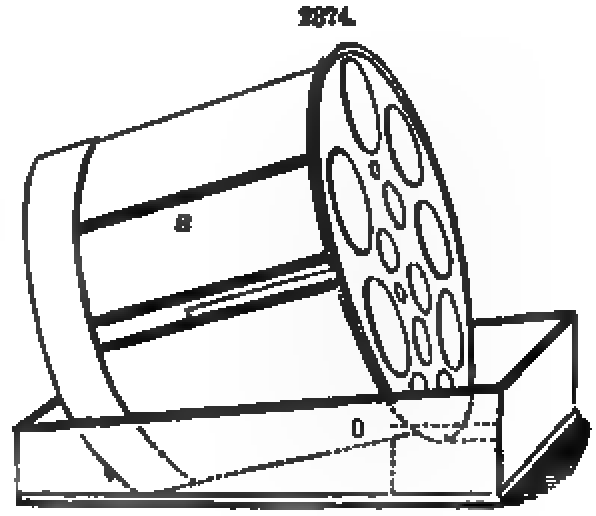

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drical case *A*, Fig. 2373, suspended on trunnions in a frame, and capable of rotation by the crank-handle shown. The cylinder is open at both its extremities, to which however covers are fitted. *B*, Fig. 2374, is a nest of cylinders, seven in number, and secured between heads; no two of these vessels are of the same size, the diameters decreasing from the largest down, in regular proportion. This assemblage of cylinders fits into the case *A*, and in said vessels is placed the water to be congealed. As the object is ultimately to produce a uniform lining of ice in each cylinder, it follows

that the quantity of water introduced in each must be measured with accuracy. This is easily done by the tray *C*, in which there is a ledge, upon which the nest *B* rests, and is maintained at such an angle that only a certain amount of water can be poured out of the cylinders, which amount is obviously directly proportional to the diameter of each tube, and, all being parallel, to the angle of inclination. The compartments are next inserted in the case *A*, and the cover replaced and secured. The case is then reversed and the other cover taken off, so that a mixture of equal weights of nitrate of ammonia and water can be poured in, so as to fill the interstices of the tubes; this done, the cover is put back and fastened, and the apparatus rotated for five minutes by the crank. This period suffices to produce a moderately thick film of ice around the interior of each cylinder, and these films can be easily taken out; it remains only to fit one cylinder of ice into the other, and so to continue until all are fitted together, as shown in Fig. 2375, to produce a solid block of ice weighing 11 lbs.

The same inventor has also contrived a dynamic refrigerator, which consists of a revolving disk, formed of a metallic tube bent into a complete spiral, having one end open and the other end communicating by a hollow shaft with an external tube communicating with a worm contained in a separate vessel, and terminating in a discharge-pipe, with outlet into another vessel containing the revolving disk, to which a slow movement of revolution is imparted by a driving-pulley and belt, making say one turn per second. The disk is half immersed in cold water, and as the exterior surface of the disk above water is continually wet, it exposes considerable evaporating surface. At the same time a continuous stream of water is forced through the hollow spiral, parting with some of its heat under the influence of the external evaporation and radiation, which is intensified by the addition of a ventilator. The current, being thus lowered in temperature, refrigerates in its turn the liquid to be cooled in the vessel. The lowering of temperature thus obtained varies according to the hygrometric condition of the atmosphere; the minimum effect obtained, under the most favorable circumstances, amounts only to a difference of 5° to 6° F., while the maximum difference obtained in sunlight is between 32° and 33° F.

ICE-YACHT. The construction of this form of vessel, which is designed for traveling upon the frozen surface of rivers, etc., is fully detailed below. The rigging is similar to that of ordinary sailing sloops. The notable feature of the ice-yacht's performance is its great speed, which often ex-

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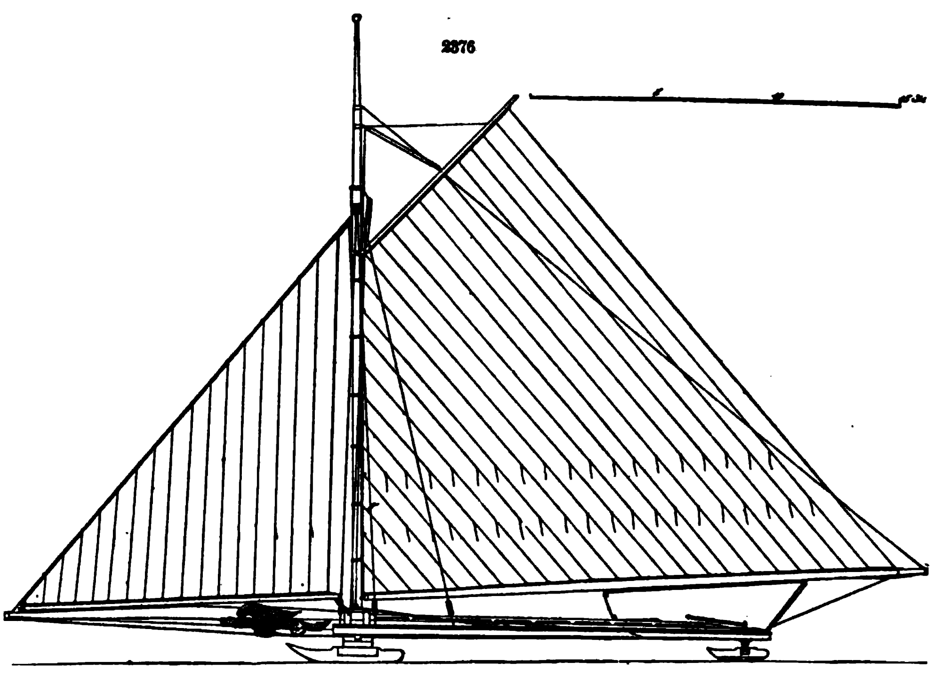


ceeds 65 miles an hour, outstripping (paradoxical as it may seem) the wind which impels it, except when the breeze is directly astern.

The following description refers to the Whiff, which was exhibited at the Centennial Exposition by her owner, Mr. Irving Grinnell:

The Whiff, of which full detailed drawings are given in Figs. 2376 to 2379, is, as will be seen, sloop-rigged. The hull, if it may be so called, is composed of the keel or centre timber and two curved side timbers, joined at the mast by two curved timbers bolted on to them, and at the stern by a semicircular continuation. The mast rises from the keel and the mast-bench, the chief timber of the latter being the runner-plank, at the ends of which two runners are bolted. This runner-plank is bolted to the under side of the side bars, and runs under the keel. The hull proper of the boat commences at the mast-bench, extending over less than half its width, and runs back in the form of an ordinary boat to the rudder end. The keel extends from here to a little way beyond the mast,

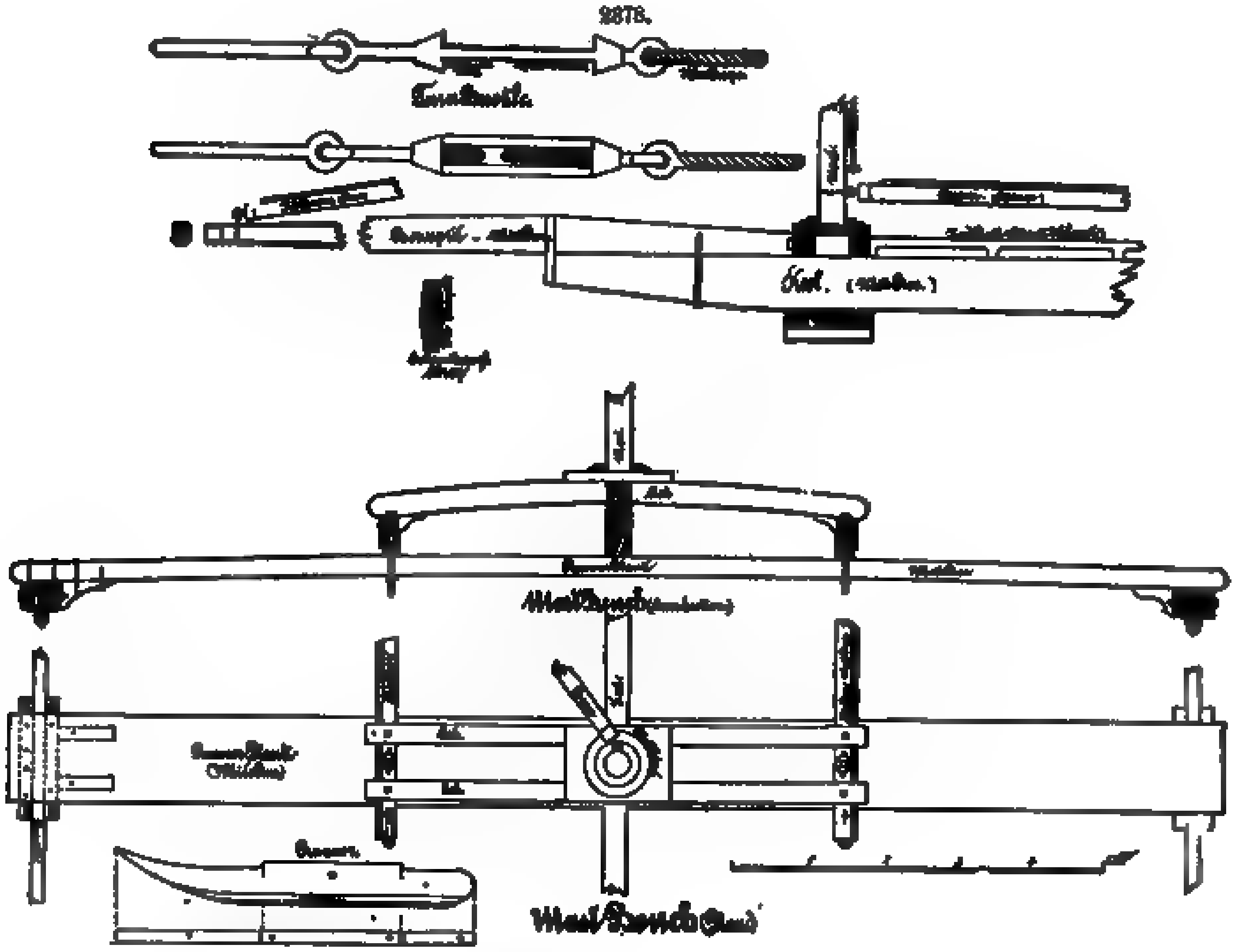
where the bowsprit is strapped on to it, and extending out forms the only hull timber in front of the mast. The deck occupies the hinder part and less than half of the hull. The rudder consists of a movable skate or runner, worked as in an ordinary vessel. The mast and bowsprit are very rigidly stayed by wire-rope shrouds. From the general design down to every detail, the object has been to give great strength and rigidity with the least possible amount of timbering necessary to secure this end.

The general dimensions of the Whiff are as follows: Total length, from the tip of her bowsprit to the end of the main boom, 40 ft. Total height, from masthead to the plane of the runner edges, 25 ft. 3 in. From end of bowsprit to extremity of deck, 31 ft. 4 in. The mast rises 21 ft. 4 in. from the deck level, and has a topmast which extends 3 ft. 8 in. farther up; it is 4 in. in diameter at the bottom, and 3 in. at the top. The bowsprit is 15 ft. in length, 8 in. deep at the ends, curving to 6 in. where it is strapped by an iron band on to the keel. It is additionally secured to the keel by a bolt running through both. The jibsprit is 13 ft. long, 2 in. at ends, rising to 2½ in. in diameter at the centre. The main boom is 24 ft. in length, is fastened to the mast by an eye and staple, and is 2½ in. at the ends, rising to 4½. The gaff is 9 ft. long, 2 in. in diameter, and is jawed on to the mast. Runner-plank, 16 ft. long, 1 ft. wide. Runners, 4 ft. 10 in. long. Rudder-skate, 2 ft. 5 in. The deck is of narrow, closely jointed, alternate slips of cedar and spruce, laid across the boat, and 5½ in. below the top of the side bars. The mainsail has a hoist of 13 ft. 8 in.; foot, 23 ft.; head, 8 ft. 4 in.; and leach, 24 ft. 3 in. The jib has a hoist of 14 ft. 8 in.; foot, 12 ft. 7 in.; and leach, 19 ft. 10 in. The total sail area is 347 sq. ft. The sails are made of heavier canvas than that usually used for a sea-going yacht of the same size, and each strip is double-bighted to give the sail the necessary stiffness. The mast, bowsprit, jibsprit, keel, side bars, and runner-plank are of white pine. The boom and gaff are of spruce. The curved timbers which brace the side bars are of ash. The handrail is of walnut, and the side bars are cased with the same wood, being also ornamented with a gilt beading.

The shoes of the runners are cast, and are bolted on to the skates, which are of white oak, by means of four screw-bolts each. This runner, 4 ft. 10 in. long, as before mentioned, and 7 in. high, is bolted between two horizontal oaken bars, 1 ft. 7 in. long, 4½ ft. deep, and 2½ in. wide, which, in their turn, are bolted to the runner-plank, the whole being braced to the runner-plank by two side pieces. The bowsprit is strapped and bolted on to the keel as shown in elevation and section in Fig. 2378. The iron strap is 2 in. wide and half an inch thick. The jibsprit is fastened to the bowsprit by means of an eye and staple. The shrouds are kept taut by means of turn-buckles, like that shown in Fig. 2378, which connect them with their staples. The shrouds are of the best galvanized charcoal iron, seven-sixteenths of an inch in diameter. A black-walnut handrail runs on the keel from the mast to the tiller. As the rudder and post are most important parts of the yacht's build, we have given the full details in Fig. 2379. The shoe is bolted on to the oaken rudder-skate, 2 ft. 5 in. long, by three screw-bolts, the latter being pinned on to the rudder-post. A rubber spring on the rudder-post is set between the shoulder and the cast-iron bottom plate let into the deck. A brass top plate is let into the keel, the tiller being fastened to the rudder-post by a screw-nut. The rudder-post is 1 ft. 3½ in. long. The tiller, whose handle is bound around with small rope, is 2 ft. 6 in. in length.

The rudder-shoes, as well as those of the two runners, are of cast iron. Steel has been tried, but

2878.



2879.

was found to be too hard. If the ice be smooth, and free from snow, etc., the greater speed is obtained with sharp skates; they are filed so sharp that they cause a hand-nail to fluff when it is drawn over them. On the contrary, when there is snow-ice, ice with a rough surface or partially covered with snow, or when the weather is moderate and disposed to thaw, the yacht sails much faster with slightly dulled shoes. The shoes, sharpened up with a file, can, when desired, be quickly roughened with emery-paper. If the edges need sharpening, a fine file or an oil-stone will accomplish in a short time the desired result. Steel shoes would not allow of these sudden transitions, while those of cast-iron do. All the iron work on the Whiff is nickel-plated, and a high degree of finish is observable on every part of the vessel.

When sailing, a sail-shelter from the wind is erected at the fore part of the deck, if desired.

The Whiff is ornamented with a very artistic figurehead, representing a griffin. Being built of the best possible material, and elaborately gotten up, this ice-yacht cost her owner $700; but a boat equally good, without the same degree of finish, can be built for from $350 to $400. (See *Scientific American Supplement*, No. 63.)

IMPACT. See DYNAMICS.

IMPETUS. See DYNAMICS.

INCLINED PLANE. For discussion of the inclined plane as one of the mechanical powers, see STATICS.

Inclined Planes on Railways.—The heights, lengths, and other particulars of the Gordon and Mahanoy inclined planes on the Philadelphia and Reading Railway are as follows:

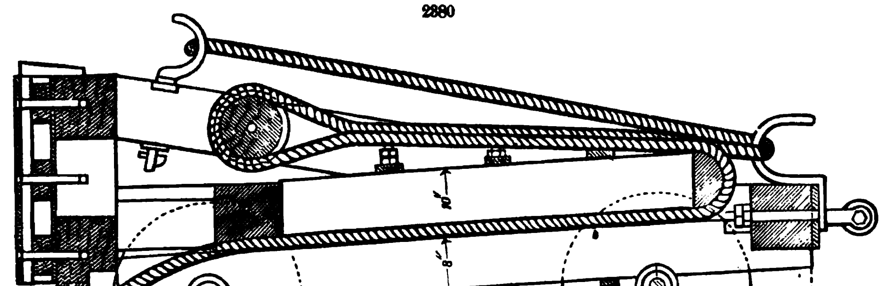
Dimensions, etc., of Inclined Planes on Philadelphia and Reading Railway.

NAMES.	PLANES.				MAIN ROPE.					TAIL ROPE.				Number of Wooden Pulleys.
	Total Length.	Height of Head above Tide.	Height of Foot above Tide.	Total Elevation.	Total Length.	Length from Truck to Truck.	Diameter.	Weight per Foot.	Made of	Total Length.	Length from Truck to Truck.	Diameter.	Made of	
No.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	In.	Lbs.		Feet.	Feet.	In.		
1. Gordon.....	4,650	1,519	1,250	318	5,105	4,992	2¼	8¼	Iron wire.	4,836	4,736	1¼	Iron wire.	598
2. Gordon.....	4,755	1,206	802	404	5,225	5,024	2¼	8¼	"	4,950	4,810	1¼	"	669
Mahanoy...	2,410	1,478	1,124	353	2,200	2,800	2¼	8¼	Steel wire.	2,600	2,500	1¼	"	506

The planes are described as follows in the *Engineer*, Feb. 2, 1877:

"The track down the Gordon planes is double, a train of loaded cars ascending on one track and the empty cars descending on the other, and alternating each trip. Lying between each pair of ordinary rails of 4 ft. 8½ in. gauge are others of 3 ft. 4 in. gauge, extending from a few feet at the head of each plane respectively down the incline, and each terminating in a small tunnel between and below the ordinary rails—to receive the 'safety-trucks' running on these internal rails—some few feet beyond the foot of the plane. The internal pairs of rails are spiked to the same sleepers as the ordinary ones, till just as they reach the tunnels mentioned, when they descend by a rapid incline, and lie out of sight, allowing the cars to pass clear over them. The safety-trucks, or 'Barneys,' as the workmen term them, are strongly built of timber, and mounted on four wheels 26 in. in diameter; the

2380



front end forms a spring buffer by means of India-rubber, or, as they term them here, 'gum' springs. The construction will be readily understood from Fig. 2380, which is a sectional view. The one end of main rope passes down under the front of truck, to keep it low to miss the axles and under-gear of the cars, and is coiled over a small drum on the truck and firmly secured; the rope then extends

up the track, passing round the two main drums in a manner to be presently described, and is then, by means of a large horizontal sheave, diverted and thrown into the centre of the other track and secured in the same manner to the other safety-trucks. The length of this rope is so adjusted that the one safety-truck is standing at the head of the plane while the other is out of sight in its tunnel at the foot. The rear ends of these trucks are connected together by a tail rope, also passing round a diverting sheave to spread the rope to the centre of tracks—thus forming, as it were, an endless rope with the two trucks in its centre, but with the ropes of different size. The main one is 2½ in. diameter iron-wire rope, with independent iron-wire-rope centre, and the tail rope is 1½ in. diameter, of similar make; its purpose is to keep the main rope tight and the trucks equidistant, and prevent its jerking and lashing the roadway, and it also insures the steady ascent and descent of the wagons. An equal tension is obtained, and the variations in length according to temperature allowed for, by the arrangement of the movable horizontal rendering sheave around whch the tail rope passes at the base of the plane. This sheave is of cast iron, 8 ft. diameter, and is fixed below the roadway, and on the same level, and a little in the rear of and between the two tunnels, for the reception of the safety-trucks. It is fixed in a frame with small wheels running on a pair of rails, allowing it a few feet play either backward or forward; to the back of this carriage carrying the sheave is attached a chain led away horizontally by a system of pulleys to the side of the line; then passing up to the top of a wooden gallows, it is fastened to a suitably weighted box sliding vertically up and down between guides as the carriage moves on its rails, the weight of the box of course being adjusted to keep the rope at the right degree of tension. There are also two smaller sheaves or pulleys fixed, one in the rear of each tunnel, spreading the tail rope out as it leaves the larger sheave to the centres of the tracks. The small pulleys for carrying the rope are made of wood, and fixed at intervals of 15 ft. apart centre to centre; they only last about a week each. The life of a main rope is based on its tonnage capacity, and it is limited to the raising of 2,000,000 tons; after having performed that amount of duty it is removed and a new rope substituted. This maximum was adopted from experience, and has worked very well. It is also daily subjected to a rigid examination, and should a fibre of one of the wire strands be found to have given way, the rope is cut to ascertain the state of the interior, it being often found worn inside from the abrasion of the wires on each other when presenting a sound exterior. The engine and boiler houses are situated at the head of their respective planes. There are 15 boilers to each pair of engines, 3 ft. diameter and 26 ft. long, plain cylindrical type, and set in the ordinary way with a flash flue, and carry a pressure of 75 lbs. per square inch. This kind of boiler, seldom exceeding 3 ft. in diameter, is generally used throughout the whole of the mining district.

"The machinery is situated beneath the roadway, and consists of a pair of engines with 30-inch cylinders, 6 ft. stroke, with link motion, and coupled on the edge of shaft, on which is fixed one of the two main drums, which are geared together; the one farthest from the engine is fixed a little lower than its fellow to allow the rope to clear it; this and the general arrangement will be understood by reference to the drawings. Both drums are the same size, viz., 12 ft. 5¼ in. diameter; the teeth are 4½ in. pitch and 10½ in. on face, as will be seen by the section of rim of these drums. The centre of the teeth is 2 in. to one side of the centre of wheel, while the centre of the oak blocks grooved for the rope is 8 in. from its centre on the opposite side. These wood blocks are inserted endways of the grain to bite better. The section of rim shows the shape to which they are cut, corresponding to the recess on the side of wheel, and to the shrouding which is firmly bolted up against them. The drums are cast in segments and bolted together; the main rope passes three-quarters round each of them, describing a form somewhat resembling a figure 8, and the one end leads down to the centre of the right-hand track, being in a line with it, and the other passes round a fixed horizontal rendering sheave of 11 ft. diameter, that being the distance from centre to centre of the tracks, which brings it in centre of left-hand track, the ends being attached as before mentioned to the respective safety-trucks. The working is as follows: The loaded wagons to be raised, usually six or seven, are pushed up to the foot of the incline and just in advance of the tunnel in which the safety-truck is lying out of sight; the empty wagons to descend are run up against the other safety-truck standing at the head of the incline, the engine is started, the empties begin the descent, and the safety-truck emerges from the tunnel and pushes the loaded wagons to the top of grade, where they are shunted out of the way, and the empties run against it ready for descent, while the full ones are also being pushed up to position at the foot of grade, the empty ones there having been removed to a siding.

"The heaviest load raised in one trip is 95 tons, including cars and contents, but, of course, it is partly balanced generally by descending empties. The number raised from the valley to the top of Broad Mountain, over the two Gordon planes, is about 90 per hour. In one month in 1876 49,000 loaded cars were raised. There are extensive sidings for the accommodation of a large number of loaded and empty wagons at the head of the plane and in the valley. For shifting the wagons and forming the trains pushing engines are used."

Fig. 2381 represents an elevation of the winding engine, and Fig. 2382 shows the inclination of the plane.

"From the altitude, length, and other particulars of the Mahanoy plane given in the table, it will be seen that it is much shorter, but also steeper, part of it rising 1 in 4, than those previously described. About 125 loaded cars per hour are raised from valley to top of Broad Mountain, overcoming an elevation of 353 ft. in about 2,400; the number of cars per trip is fewer, the maximum weight of train, including cars, being about 60 tons—this made up by the greater rapidity with which the plane is worked, the speed being at the rate of nearly 20 miles per hour. The general arrangement of rails, safety-trucks, etc., is similar to those of the Gordon. The main rope is of steel, but of the same size and style of construction and tonnage capacity as at Gordon. The engines are more powerful; diameter of cylinder 32 in., with 7 ft. stroke. The two main drums are 14 ft. diameter,

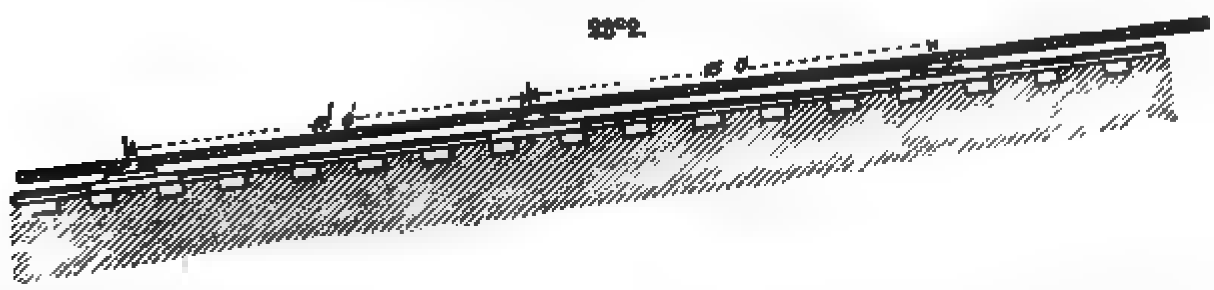
and have oak blocks grooved for the rope on each side with the teeth in centre, as per drawing of section of rim, Fig. 2383, the rope passing twice round each drum instead of once as at the Gordon. This is rendered necessary to prevent slip at the high speed at which they are run. Fig. 2383 clearly illustrates this arrangement. At 1 is the back rendering sheave; 2, main drums; 3, sheaves to change alignment of rope at drums: 4, sheaves at top. Fig. 2384 is a section of main drum at *A*.

2381.

"The fixed rendering drum in rear of engine-house is 14 ft. 6 in. diameter, and the movable one for the tail rope at foot of plane 10 ft. 8 in. diameter. As an example of the work this machinery is capable of doing, during the busy season of 1876 it raised from the valley to the summit an average of 16,000 tons, including weight of cars, for each working day."

Inclined Planes on Canals.—On the Morris and Essex Canal the construction of the inclined plane

2382.



is commonly as follows: A track of heavy rails is laid on the plane, which has a grade of about 15°, and on this the cradle containing the boat ascends at the rate of five or six miles an hour. At the summit is the motor, consisting of a water-wheel driven by the water on the upper level. The wheel is connected to a shaft carrying a drum on which is wound a wire rope about 2 inches in diameter, which contains the boat, and which forms a car for its conveyance. This car is a heavy frame running on flanged wheels, and descends a sufficient distance into the water to enable a boat to float into it, where being secured the car and boat ascend or descend the inclined plane together. From the forward end of the car the wire rope passes over anti-friction rollers, between the rails of the track, to and around a large submerged wheel some 100 feet distant from the summit; thence over the drum and other friction rollers by the side of the track to another submerged wheel at the foot of

the plane, around which it passes, and is attached to the rear end of the car. The boat is made in sections, to enable it to accommodate itself to the inequalities of the track when passing over the summit.

Arriving at a plane, the boat is drawn into the car in the order of its arrival, the team is unhitched, the boat secured in the car by hawsers, and its two sections disconnected. The engine is then started. After passing the summit the brakes are put on, and the car descends into the water, where the boat floats out of it, and the tow-rope is again attached. In one place the above-named canal has a fall of 200 feet, 80 of which are overcome by a single plane 800 feet in length, and the remainder by means of locks.

INCRUSTATION. See BOILERS, STEAM.

INCUBATOR. See AGRICULTURAL MACHINERY.

INDIA-RUBBER, or CAOUTCHOUC. The inspissated milky juice of a number of trees and plants found in Mexico and Central America, in Brazil, Guiana, and Peru, and in the East Indies. The *Jatropha elastica* (Linn.) of Brazil, which flourishes abundantly, and the Central American trees, furnish the greatest quantities of rubber to commerce. The terms by which the material is known in manufacture are Pará, Madagascar, Guayaquil, Borneo, West India, Assam, etc., after the places where it is grown. The mode of obtaining rubber is as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of India-rubber) is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay made in the shape of pears are plunged into the liquid, and afterward passed over a fire made of the branches of trees, in order that the layer of India-rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The balls are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure. Sometimes a thin board is used as a nucleus, on which the sap is deposited and agglomerated; in this case, the mass of India-rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest India-rubbers are those which are gathered in this way, such as Pará and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter. When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption. When they are very thin, they are rolled up like a skein of thread, and the appearance of the India-rubber in balls serves to remind one of a clue of worsted.

The method of preparing the crude rubber varies. One process consists in softening the raw material in hot water, cutting it into pieces of about 1½ cubic inches by saws, and flattening it between two cylinders, placed horizontally, the distance between which is regulated at will by set-screws. These cylinders are of different velocities; it follows, therefore, that, independently of the pressure which the India-rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and under the continuous action of a stream of water they are easily carried off. Under this process, which is repeated eight or ten times, every time bringing the two cylinders nearer together, all the impurities vanish, and the rubber assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

The kneading is then done in a "devil," which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp-pointed teeth disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute, carries along with it the grained sheet, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it toward them. There results from this a perfect process of trituration, which forms the sheet of rubber into a compact mass. It then passes between steam-heated compressing cylinders, in which it is compressed until it presents the aspect of a rolled-up sheet of firm texture, close and exceedingly smooth. This gives the finish to the preceding operations.

The most approved method of treatment, however, and the one in general use in this country, consists first in softening the rubber in large tanks of boiling water. A mass weighing from 10 to 20 lbs. is then thrown upon a pair of strong fluted cast-iron cylinders, between which it is masticated into small pieces and washed by streams of hot water which fall upon it from a perforated horizontal pipe. After being passed several times through the machine, it is taken to another, similar in construction (Fig. 2385), but having a pair of smooth cylinders in place of the fluted ones. These produce an enormous pressure, which packs the pieces together in the form of a mat; this is also passed several times in succession through the machine and washed by the dripping of hot water, as in the preceding operation. When the mat is sufficiently compacted and washed, it is taken to a drying room, a warm chamber heated by steam, where

it is allowed to remain from four to six weeks, until it is thoroughly dry; for if it were attempted to work the material while it contained any moisture, an inferior fabric would be the result.

Pure India-rubber is used only for special purposes. The requirements of industry demand various qualities of products. possessing properties suitable to the different uses to which they are applied. It is the mixture of blocks of compressed rubber with foreign matters which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances which is regular and uniform throughout; it is also during this operation that the material for imparting any desired color is added in the form of powder. When the rubber is not rolled, it is moulded; the paste being placed in a mould, which is exposed to a temperature varying between 125° and 150°. The material is thus caused to expand and penetrate into every part of the mould. If a hollow article is required, a little water is introduced, which, being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

When rubber has been agglomerated in a "devil," the mass is sometimes rolled between cylinders, and several thick sheets thus obtained are compressed by hydraulic pressure into blocks, which are cut up into sheets. For this purpose the block of rubber is held in movable bearings, and the cutting knife is carried in a slide. The knife is kept continually wet. The sheet of rubber, as it is produced by the action of the knife, is passed over and under guide-rollers, and over a drawing or taking-up roller, which, revolving and being covered with India-rubber, has sufficient bite or hold on the sheet to draw it forward with the required tension. The speed of the roller is required to decrease with the size of the block of rubber under operation; for as the sheet is cut from it less length is produced during each revolution of the block, and as it decreases in circumference, its rotatory speed being the same, the roller in contact with it will be driven slower, and will communicate its decreasing velocity by means of the crossed straps to the taking-up roller, so that the sheet of India-rubber will be taken up as it is produced and deposited in folds in front of the machine.

Raw India-rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of the cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, which is most sensitive to the variations of heat, has the effect of preventing those grave inconveniences arising out of it, and of making India-rubber a substance that can be utilized under any conceivable circumstances. That is the object attained by vulcanization.

The agent employed for vulcanizing is sulphur. Its action on India-rubber is similar to that on fatty substances, which, when mixed with it in the proportion of one to five, and heated by a temperature of about 200°, produce a substance offering a good deal of resistance, and presenting almost the aspect of India-rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with the heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to adhere.

The usual method of vulcanization and treatment in connection therewith is as follows: After the sheets are prepared as described by the masticating and compressing machines, and are thoroughly dried, they are passed successively through three mills. All the mills are of similar construction to the one already represented, except that in each machine one cylinder is made to revolve twice as rapidly as the other, in consequence of which the material is thoroughly ground and mixed. But while undergoing the process the continuity of the mat is not destroyed, for it retains its form, although a careful scrutiny will show that a constant and rapid change of position is going on among the particles. The cylinders are hollow and are supplied with steam, which keeps them at about 220° F. in the first mill, and at a little lower temperature in the other two. The first mill merely works and compresses the material into a firm thick sheet of a homogeneous texture, preparatory to the incorporation of the sulphur and whatever other ingredients are to be added, which operation is performed entirely in the second mill..

Taking as an example the manufacture of India-rubber hose for steam fire engines, as carried on at a large establishment in New York, the subsequent steps are as follows: After leaving the first mill, about 5 per cent. of sulphur (and in some cases certain mineral matters, as white lead) is thrown upon the sheet while it is passing down between the cylinders. The mixing at first causes disintegration and the separation of the material into shreds; but union is speedily reëstablished, and the mass again becomes homogeneous, and will retain its pliability and elasticity after cooling. This, however, is not allowed to take place until it is passed through the third or finishing mill. Here the sheet is passed between the cylinders over and over again, until its pliability and working qualities are perfected, and as far as possible adapted to being spread upon canvas. This operation is performed in an adjoining room upon a calender (Fig. 2386), a machine somewhat similar to that used in cotton-bleaching establishments. The rubber is first of all again passed through a pair of cylinders in a machine called a feeder, which is also similar to the mills through which it has already passed. This feeder stands near the calender, and its purpose is to knead and temper the India-rubber to the exact condition in which it can be best applied to the cloth. It is taken in handfuls at a time and fed to the calender between the two upper cylinders represented in the figure, but upon the opposite side to that which is shown. The surfaces of the two cylinders are so prepared that the rubber adheres in a thin sheet to the lower one of the two, which in its revolution brings it in contact with the third or next lower cylinder, over which the cloth is being passed, forcing it thoroughly into the meshes of the fabric. After one side of the canvas has been coated it is turned, and the rubber is applied to the other side. It is then taken to a larger calender, where another coating is applied to one side, the whole sheet being well consolidated under powerful pressure.

The cloth is now ready to be made into hose, and the operation is commenced by cutting it into

strips diagonally, so that both warp and weft may receive the strain to which the hose may be subjected, thus greatly increasing the strength of the fabric. The strips are cut in width a little more than twice the intended circumference of the hose, so that one sheet will form two thicknesses of its walls. The inner layer of the pipe is formed by a thick sheet of uncanvased vulcanized rubber, which has been also prepared in one of the calenders. This is cut of the proper width, and wound round a long iron pipe used as a mandrel, and its edges are lapped over one another, firmly pressed together, and permanently joined by a small grooved roller held in the hand of the workman. Before being applied, the inner surface of this sheet of rubber must be coated over with a powder of some substance which will prevent adhesion to the mandrel, so that it may be removed after the hose is finished. The best substance is soapstone, or steatite. The lapping edge must be carefully left untouched with this material, or perfect union will not be possible. Around this inner coating are now successively wrapped two strips of the bias-cut rubber canvas, and over this another and outer coat of pure vulcanized rubber, making six coats in all, four of which are of rubber canvas. It is claimed that hose of 2 in. calibre, made in this manner, is capable of resisting a hydrostatic pressure of 400 lbs. per square inch at a temperature of 60° F. Each length of hose is usually made 50 ft. long, which has been found the most convenient for use on the hose carriages, the lengths being joined as required by couplings. After every layer has been wound over its concentric fellow, and also during the process, the workmen make use of their rollers to compress and consolidate the hose. After all the layers have been applied, the pipe is taken to another bench, where it is covered with four or five layers of cotton cloth, and then, with several others, it is placed upon a long carriage which runs upon rails into a large hollow cylinder, Fig. 2387, which is heated by live steam, or steam which is not superheated, coming immediately from the boiler, and usually at a pressure which will give it a temperature of about 240° F. When the rubber has been confined in this cylinder, at this temperature, for eight or ten hours, the true vulcanization or union of the caoutchouc with the sulphur takes place, accompanied with the disengagement of sulphuretted hydrogen gas. This is one of the most important parts of the process of manufacture, and upon it, as well as upon the mixing of the ingredients, depend the strength and elasticity of the product. The heat should be raised gradually and maintained at a determined point till the vulcanization is completed, and then should be immediately withdrawn. In manufacturing engine hose, the New York Gutta Percha and Rubber Manufacturing Company mix a certain amount of carbolic acid with the caoutchouc, which it is claimed preserves the hose and shortens the process of vulcanization. An ingenious register is in use at their factory, the invention of Mr. John Murphy, by which the appli-

2387.

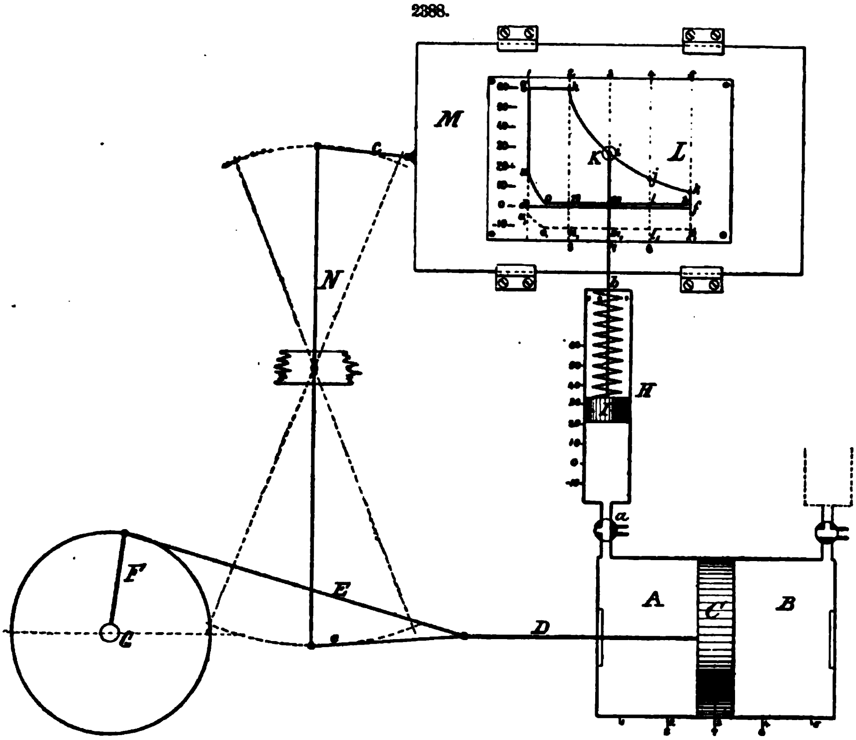
cation of a steam-pressure gauge to clockwork records the different degrees of temperature and their duration which may have been reached during the vulcanizing process, which is generally performed during the night, under the care of one or two men.

When caoutchouc is intended for car springs, about 5 per cent. of white lead and variable proportions of carbonate of lime are added, with 5 per cent. of sulphur. This makes the product more solid and substantial, and capable of supporting greater weight without too much compression, which is objectionable. In the manufacture of ebonite, a much larger proportion of sulphur is used; and in the cheaper kinds, when great strength is not required, various earthy substances are employed. But sulphur and caoutchouc alone, when properly mingled and raised to the required degree of heat, produce the best article. The temperature necessary to effect the proper result varies with the proportion of the ingredients, and ranges from 250° to something over 300°, this also being more or less modified by the time employed.

When India-rubber is woven into fabrics, it is prepared for the purpose by slicing it into threads, with knives worked by machinery and kept wet. These threads are wound upon cylinders in a state of tension, and are woven into the fabric in this condition. In the early manufacture of fabrics of this kind a process technically called "shirring" was employed. The elastic threads, in a state of tension, were passed between rollers, and then between two other rollers over each of which was passed a strip of cloth, cotton, or silk. This brought the threads between the two layers of cloth, and the latter having been prepared with a coating of India-rubber cement, they were held there. One of these shirring machines, together with a machine for cutting the threads, was the invention of James Bogardus of New York, and was extensively used for a number of years. The goods made by that process have however entirely given place to woven fabrics; and the cutters now used are single circular knives, revolving with high speed, cutting sheets wound upon cylinders, which are given a slow rotary as well as a side motion, by which the thread is cut in a spiral.

INDICATOR. The steam-engine indicator is a device for recording, by means of a diagram, the successive pressures in a steam-cylinder at every point of the double stroke. It is also used similarly to measure the pressures in the cylinders of air, gas, and water engines and pumps. The principles of the construction and operation of an indicator will be understood by referring to Fig. 2388, in which $A\,B$ represents the cylinder of a steam-engine, C the piston, and D the piston-rod of the

2388.



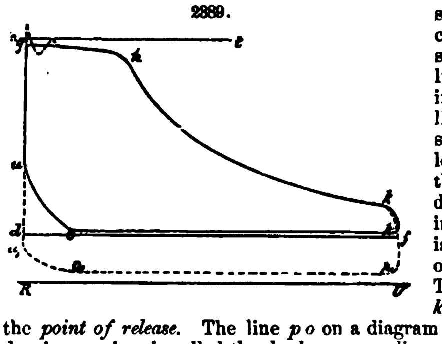
same connected to the load through the connecting-rod E, crank F, and shaft G, as sketched, or in any customary manner. The remainder of the figure shows the principal features of an indicator on an enlarged scale, though modified slightly in detail to facilitate explanation. H is the indicator-cylinder, which is connected to the end A of the main cylinder through a short passage regulated by a cock a, which is so constructed as to put the indicator-cylinder in communication with the atmosphere when the passage to main cylinder is closed. Suitable openings are provided to keep the upper part of the indicator-cylinder in communication with the atmosphere at all times. I is the

indicator-piston, which is connected to one end of a spiral spring, the other end of which is held stationary in any suitable manner. *K* is a pencil, which is moved up and down by the piston *I*, either by a direct connection through a piston-rod *b*, as shown, or through a system of levers. The pencil is adjusted to bear lightly upon a piece of paper *L*, which is secured to a slide *M*, receiving a lateral movement from the main piston through the lever *N* and links *c* and *e*, as shown. Usually, however, the paper is secured to a drum, which is partially revolved back and forth by levers, cords, and a spring hereafter described, which impart to the paper the reduced movement of the main piston in the same or the opposite direction. The compressions or extensions of accurately constructed springs are proportioned to the intensities of the forces impressed; hence, if the resistance of the spring of the indicator be such that it will require 15 lbs. to compress it one inch, and the piston *I* have an area of one half inch, the pencil will be moved one inch by a pressure of 30 lbs. per square inch on the piston, and proportionally for other pressures. In such case the scale of the indicator is called 30 lbs. per inch, or the spring is marked $\frac{1}{30}$, meaning that the movement is one-thirtieth of an inch for each pound pressure per square inch on piston. Indicators are usually provided with several springs of different strengths—scales of 10 lbs. per square inch being used for low-pressure air-engines, scales from 16 to 32 lbs. per square inch for ordinary low-pressure condensing engines, and of 40 to 60 lbs. or more for high-pressure engines.

Referring to Fig. 2388, if the engine be in operation and the cock *a* shut, the atmospheric pressure will be on both sides of the piston as previously explained, and the piston and pencil in position opposite the point marked 0 on the scales shown, when, by the lateral movement of the paper, the line *d f* will be traced, called the *atmospheric line.* When the cock *a* is turned to admit steam from the main cylinder *A* to the indicator, the piston of the latter will be forced up and down; and this movement, combined with the lateral motion of the paper, will cause the pencil to trace a diagram in which the vertical height above the atmospheric line at any point will represent the pressure in the main cylinder at the portion of the stroke corresponding to the horizontal position of the point. For instance, if the main piston be at position 1, or just commencing its stroke, line 1 on paper *L* will be opposite pencil *K*. If steam of 60 lbs. pressure be then admitted to the main and indicator cylinders, the pencil will be carried up to the point *g* opposite 60 on the scale at the left. If the steam remains at 60 till the main piston reaches position 2, line 2 on the paper will be moved opposite the pencil, and the latter remaining stationary will trace the line *g h*. If the steam be now cut off, the pressure in the main cylinder will fall rapidly, and by the time the main piston reaches position 3 the paper will be in the position shown, and the pencil will have dropped to *i*, or opposite about 27 lbs. on the scale of pressures as shown, tracing in its downward movement, combined with that of the paper, the curve *h i*, the height of which at any point shows the pressure in the main cylinder at the corresponding portion of the stroke. The pressure will gradually fall in the cylinder as the piston advances, and the curve *i j k* be traced on the diagram. At or near *k* the steam will be exhausted and the pencil fall to *p*, showing a back pressure of about 1¼ lb., which may remain nearly constant while the main piston is passing the positions 6, 7, and 8 on the return stroke, so that the pencil will trace the line *p o*. If at *o* the exhaust-port be shut, the back-pressure vapor will be compressed and the pressure rise, forming the curve *o u*; and about the time the piston reaches the end of the stroke steam will be again admitted and force the pencil to *g*, tracing line *u g*, and the operations be repeated. If there be a vacuum in the cylinder during the return stroke, the atmospheric pressure will force the piston *I* below the point 0 on the scale, and the pencil *K* trace a back-pressure or vacuum line below the atmospheric line, as shown by the dotted line $p_1\, o_1$. The vacuum shown in a steam-cylinder usually corresponds to a reduction of pressure of from 10 to 12 lbs. The theoretical full-stroke diagram is evidently a rectangle. It is however not obtained in practice in a steam-engine, but is closely approximated in the best pumps.

Fig. 2389 is a diagram similar to the one above developed, with such modifications as are found in practice. The line *d f*, which is drawn by the instrument, is as before stated called the *atmospheric line.* A line *R U*, called the *true vacuum line*, may be drawn on the paper by hand at the distance below the atmospheric line corresponding to the height of the barometer, or usually 14.7 lbs. A line *s t* is also drawn in some cases to show the pressure in the steam-chest or boiler. The line *u g* is called the *receiving line*, and *g h* the *steam line.* The sudden rise of the indicator-piston in drawing the line *u g* often induces vibrations of the spring, making the steam line undulatory, as shown in dotted lines. At *h* is the *point of cut-off*, which theoretically should be a sharp angle, but in practice is more or less rounded, according to the velocity with which the cut-off valve is closed. Usually also the cylinder-ports are not of sufficient size to maintain the initial pressure to the point of cut-off. The result is a kind of imperfect expansion, shown by the slope of the line from *g* to *h*, which is called *wire-drawing.* The curved line *h k* is called the *expansion curve*, and *k p* or *k* p_1 the *exhaust line* or *curve*, *k* being called the *point of release.* The line *p o* on a diagram from a non-condensing engine, or $p_1\, o_1$ from a condensing engine, is called the *back-pressure line*; but the latter is more generally called the *vacuum line.* The curve *o u* is called the *cushion curve.* Pressures above the atmospheric line *d f* are called *pressures above the atmosphere* or *pressures by gauge*; and pressures above the perfect vacuum line *R U* are called *total pressures.* The pressure at the beginning of the stroke is called the *initial*, and at the end the *terminal pressure*; the two latter may either be total or above the atmosphere.

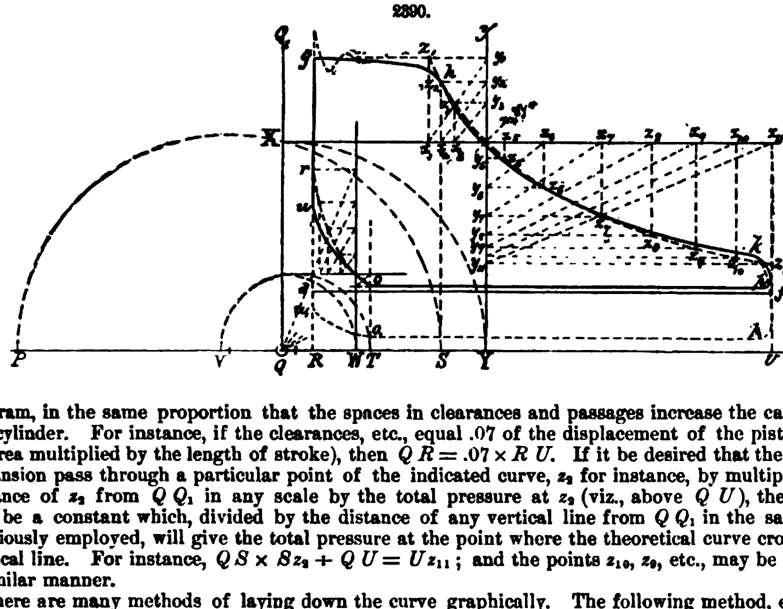
2389.



Mariotte's law of the free expansion of gases (applicable strictly only to perfect gases expanding without change of temperature) is, that the pressures are inversely as the volumes. It follows then that the products of the pressures by the corresponding volumes are severally equal to a constant. On this basis the expansion curve is hyperbolic, an equation of the hyperbola being $xy = a$. In the practical operation of a steam-engine, heat is transmuted into work, and condensation takes place in the cylinder sufficient to supply one heat-unit for each 772 foot-pounds of work. On this basis the pressures should decrease faster than the ordinates of a hyperbolic curve; and to express the relation, an equation has been developed for what is termed the *adiabatic curve*, in which the heat transmuted into work is considered, but no allowance is made for transmission to and from the steam and its inclosing walls. Inasmuch as such transmission does take place—often to an enormous extent, and always to an important degree—by which means the practical curve of expansion is usually raised to or above the hyperbolic curve, it follows that the latter practically represents all the conditions better than the adiabatic curve; for which reason, and to secure simplicity, the hyperbolic curve will be herein considered as the theoretical curve of expansion.

For various reasons hereafter explained, it is desirable to lay down the theoretical curve upon indicator diagrams for the purpose of comparing it with the indicated curve, and thereby ascertaining the condition of the engine. This may be done in several ways, two of which will be explained in connection with Fig. 2390. The first step is to lay down the perfect vacuum line $Q\,U$ at a distance below the atmospheric line $d\,f$, by the scale of pressures equal to the barometric pressures at the time, or usually 14.7 lbs. A perpendicular $Q\,Q_1$ should also be erected to lengthen the

2390.



diagram, in the same proportion that the spaces in clearances and passages increase the capacity of the cylinder. For instance, if the clearances, etc., equal .07 of the displacement of the piston (or of its area multiplied by the length of stroke), then $Q\,R = .07 \times R\,U$. If it be desired that the curve of expansion pass through a particular point of the indicated curve, z_3 for instance, by multiplying the distance of z_3 from $Q\,Q_1$ in any scale by the total pressure at z_3 (viz., above $Q\,U$), the product will be a constant which, divided by the distance of any vertical line from $Q\,Q_1$ in the same scale previously employed, will give the total pressure at the point where the theoretical curve crosses that vertical line. For instance, $Q\,S \times S\,z_3 \div Q\,U = U\,z_{11}$; and the points z_{10}, z_9, etc., may be found in a similar manner.

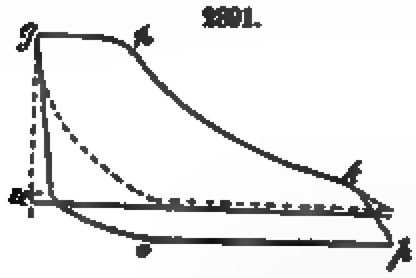
There are many methods of laying down the curve graphically. The following method, employed by the writer, is quite simple, and avoids the necessity of dividing the diagram into equal parts. First select any desired point through which the curve is to pass; multiply together the distances of that point from the asymptotes $Q\,Q_1$ and $Q\,U$ (measuring the distances with the same scale, that of pressures preferably); extract the square root of the product; lay off the value of the root from Q to X and Q to Y, and draw $X\,x$ and $Y\,y$ parallel to the asymptotes. Then, if from points x_1, x_2, x_3, etc., at different portions of the stroke, on line $X\,x$, diagonal lines be drawn to the origin, Q, such diagonals, produced if necessary, will intersect the line $Y\,y$ at points showing the pressures at the corresponding points of the stroke x_1, x_2, etc.; and drawing $x_1\,z_1$, $x_2\,z_2$, etc., parallel with $Q\,Q_1$, and $y_1\,z_1$, $y_2\,z_2$, etc., parallel with $Q\,U$, the intersections z_1, z_2, z_3, etc., are points in the theoretical curve. The square root of the product referred to may be obtained graphically by drawing $z_3\,S$ parallel with $Q\,Q_1$, laying off $Q\,P$ equal to the pressure $S\,z_3$; and drawing a semicircle through points P and S, intersecting $Q\,Q_1$ at the point X, then $Q\,X$ equals the root desired; and drawing quadrant $X\,Y$ with Q as a centre locates also the point Y. The theoretical compression curve $o\,r$ may be laid down in a similar manner, starting from o. The practical compression curve generally falls below the theoretical curve, as shown approximately at $o\,u$, on account of condensation to reheat the cylinder as pressure rises.

In most cases, when using saturated steam at short points of cut-off, the indicated expansion curve falls below the theoretical curve near the beginning of the stroke (condensation taking place to reheat the cylinder), and rises above the latter near the end of the stroke (from re-evaporation), substantially as shown. With steam quite dry and the better class of engines, however, the indicated and theoretical curves agree very closely. With very wet steam the indicated curve near end of stroke rises considerably above a hyperbolic curve run through the point of cut-off, while with highly superheated steam it often runs a little below, the same as the adiabatic curve. In vertical engines,

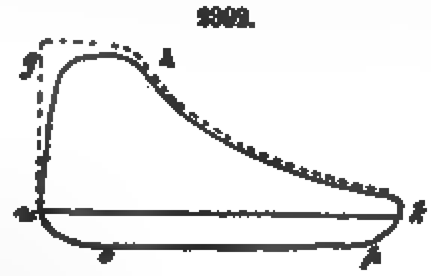
when cutting off short, water is likely to collect above the piston, distorting the diagram from the top of the cylinder by raising the terminal pressure, as shown in Fig. 2403.

Defects in the design and adjustment of valves and valve-gear, leaks of the valves or pistons, as well as the quality of the steam and the thermal condition of the steam-cylinder, may all be ascertained from indicator diagrams which have been carefully taken with a good instrument. When the eccentric is too far ahead, the diagram shows an excess of *lead*, as represented in Fig. 2391. Steam is taken at *u* before the end of the stroke, and the receiving line *u g* is inclined. With a slide-valve *the point of release k* will also be farther away from end of stroke, showing an early exhaust. In locomotives and rapidly-moving engines early steam and exhaust lead is desirable, to cushion the reciprocating parts. (See Figs. 2398, 2400, and 2401.) When the eccentric is behind, the steam and exhaust lines incline in the opposite direction, as shown in Fig. 2392. Generally, too, the steam line

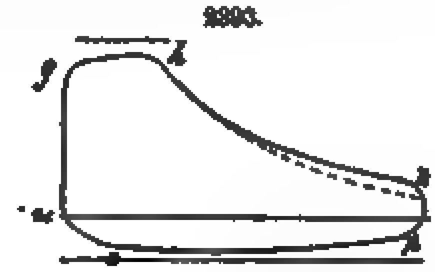
2391.



2392.



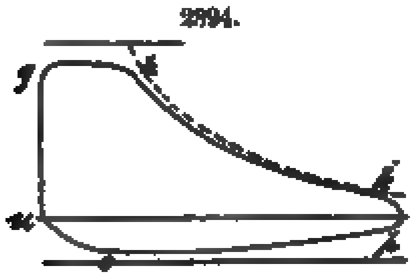
2393.



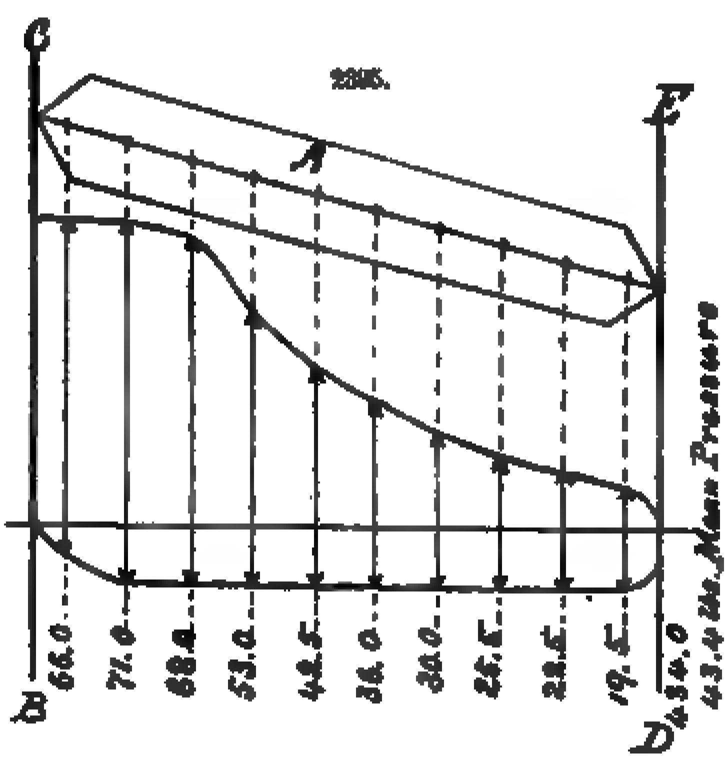
is lower than is ordinarily the case to the point of cut-off; and for fixed cut-off and constant steam-pressure, the pressure in the cylinder will be less throughout the stroke than when sufficient lead is given. When steam is wet, the steam line is usually lower than usual, and the pressure at end of stroke rises considerably above the theoretical curve. Generally, too, the vacuum at the beginning of the return stroke will be reduced, as shown in Fig. 2393. If the engine has independent steam and exhaust valves, and the steam-valve leaks, the steam line will be in its ordinary position, but the expansion curve will be above its true position, much the same as if the steam were wet. On the contrary, if the piston or the exhaust-valve leaks, both the steam and expansion lines will be low; and generally, but particularly when the piston leaks, the back-pressure line will be high and the vacuum low at the beginning of the return stroke, as shown in Fig. 2394—steam at that time being admitted at full pressure on the other side of the piston. Caution and experienced judgment are required to distinguish distortions of the diagram due to wet steam from those arising from misadjustment of the valves. When the cylinder, or part of the same, is exposed to cold, or attached to large masses of metal so exposed, the diagrams show unmistakable signs of moisture, and are of reduced area.

One of the principal uses of the indicator is to determine the *power* developed by an engine. The indicator diagram shows the pressures in the cylinder at all points of the stroke, and the first step is

2394.



2396. 2397.



to ascertain the average or mean effective pressure. This is usually accomplished by the general method employed to measure irregular figures. Ordinarily the diagram is divided into a number of equal parts, ten being customary and sufficient for most purposes; then the pressures from bottom to top of the diagram are measured with the scale centrally between the lines, and the sum of the different measurements divided by the number of ordinates gives approximately the mean pressure. It is better, however, to make the divisions so that a half space occurs at each end, and then measure directly on instead of between the lines. This can be conveniently done, when a number of diagrams are to be used, by laying off the spaces on a piece of card-board shaped like *A*, Fig. 2395, made a little longer than the average length of the diagrams, so that it may be conveniently applied between the lines *B C* and *D E*, which should in all cases be drawn at the ends of the diagram at right angles to the atmospheric line. The different points are then to be pricked through, and the division lines

drawn from the same parallel to those at the end. Ten points may be similarly arranged in a piece of wood, and all pricked into the paper at one time. The multiple parallel ruler, shown in two positions in Figs. 2396 and 2397, is furnished by the Messrs. Elliott Brothers with the Richards indicator for a similar purpose. The parallels should first be adjusted to the length of the diagram, and a dot made for the first end division. This distance should be bisected and the ruler moved bodily the half space, without permitting motion in the joints, when the ten parallel lines may be drawn across the card with half spaces at the end, the same as in Fig. 2395. The pressures by scale at the several points may be conveniently marked upon or at the side of the diagram, summed and divided by ten as shown, which will give the mean pressure. The writer has, however, found it more convenient to take off the successive measurements on a strip of drawing-paper, using a sharp-pointed knife to shift a point in the strip from the bottom of one ordinate to the top of the next. The portion of the strip used is then measured in inches, and the result, divided by one-tenth of the scale of the indicator, equals the mean pressure. This division need not be made until the gross lengths of the ordinates of all the diagrams have been summed together. When diagrams from both ends of the cylinder are taken on the same paper, as shown in Figs. 2398 to 2406, the sum of the ordinates of both may be obtained on the strip at one operation, in which case the result must finally be divided by two. The areas of diagrams are frequently measured with a planimeter, in which case the area in square inches and length of diagram in inches and hundredths are simply to be noted, when the sum of the areas, divided by the sum of the lengths and multiplied by the scale of the indicator, equals the mean pressure. When diagrams are double, the result should be divided by two, or for simplicity *half* the scale of the indicator used for a multiplier.

The system of measuring from the top to the bottom of the same diagram above provided for does not show the true effective pressure on the piston at the position where the measurement is taken. The effective pressure at any position of the piston evidently equals the pressure on one side less that on the other. This can be obtained by taking diagrams from both ends of the cylinder on the same sheet, or combining the two, as in Fig. 2398; then the effective pressure at any point may be found by measuring from the top of one diagram to the bottom of the other. In the figure the effective pressures are measured by the successive heights of the shaded figure $A\ C\ E\ G$, and the latter part of the stroke is completed against the resistance of pressures measured by the successive heights of the figure D. The average effective pressure in both ends of the cylinder will, however, in all cases equal the average mean pressure of the diagrams found in the manner above explained. For, representing the pressures by the areas, if we add the areas included in the figures representing the actual mean effective pressures for both ends of the cylinder, viz., $A + C + E + G - D$, and $B + D + F + G - C$, the sum reduces to $A + B + 2G + E + F$, which is the sum of the areas of the two diagrams, and will be, no matter what their relative areas. The method of measuring each diagram separately gives, therefore, accurate final results; and the more complex system need be adopted only when for any reason it is desired to separate the work done in one end of the cylinder from that done in the other. In some cases the steam-pressures are measured from the top of the card to the atmospheric or perfect vacuum line, and the back pressures to the same line, and the average of the latter subtracted from the former. This is in general unnecessary. By multiplying the area of piston in square inches by the mean pressure in pounds per square inch obtained as above, the mean total effective force urging the piston is obtained; and multiplying this by the speed of the piston in feet per minute gives the number of foot-pounds of work performed in a minute, which, divided by 33,000 (which equals the number of foot-pounds per minute in one horse-power), gives the number of horse-powers developed.

In obtaining the area of a piston, the area of the piston-rod should be considered. If the piston-rod runs through one end only of the cylinder, half the area of the rod should be deducted from the total area of the piston, and the result will be the mean area of the two sides of the latter. Let P equal the indicated horse-power, m the mean pressure in the cylinder in pounds per square inch, A area of piston in square inches, S length of stroke in feet, and R number of revolutions per minute: then $P = \dfrac{A \times m \times 2 \times S \times R}{33{,}000}$. For a given engine the portion of the above equation represented by $A \times 2 \times S \div 33{,}000$ is always constant, and represents the power developed by the engine per pound of mean pressure in the cylinder for each revolution per minute. It is the habit of the writer to ascertain this constant in the first instance, and keep a memorandum of it in connection with the dimensions of the engine, when at any time the power may be ascertained by simply multiplying together the constant, the mean pressure, and the revolutions per minute. Putting $K =$ such constant, $D =$ diameter of cylinder, $d =$ that of the piston-rod, and $\pi = 3.1416$; then

$$K = 2S\left[\pi\left(\frac{D}{2}\right)^2 - \frac{\pi}{2}\left(\frac{d}{2}\right)^2\right] \div 33{,}000 = \cdot 0000238\left(2D^2 - d^2\right)S, \text{ and } P = K\,m\,R.$$

Thus, for a cylinder 34.1 inches in diameter, with piston-rod 4⅞ inches in diameter, and 30 inches or 2.5 feet stroke of piston, $K = .13723$. So, when the mean pressure is 30 lbs., and the engine making 70 revolutions per minute, the horse-power $P = .13723 \times 30 \times 70 = 288.183$.

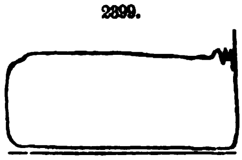
The approximate quantity of steam used by an engine may also be determined from an indicator diagram. To do this, it is necessary to ascertain the specific volumes or weights per cubic foot of

steam at different pressures. These are tabulated in works on the subject. Referring to Fig. 2390, the cylinder to the point of cut-off h, including the clearance spaces, is full of steam at the total pressure Sh. The size of cylinder and point of cut-off being known, it is easy to find the number of cubic feet included in the cylinder to that point, including the average clearance spaces for the two ends of the cylinder, which, multiplied by the number of strokes per hour, will give the number of cubic feet of steam of that pressure used per hour; and the latter quantity, multiplied by the weight of a cubic foot of steam at that pressure, equals the calculated weight of steam per hour. The amount of steam required from the boiler is, however, less than this, as the clearance spaces during each stroke are filled with steam of the final total cushion pressure Ru, so that the capacity of the clearance in cubic feet multiplied by the number of strokes per hour, and by the weight of a cubic foot of steam at the total pressure Ru, must be deducted from the previous result, and the remainder represent the calculated weight of water that must be evaporated per hour to produce the power. The calculation may in like manner be made for the volume and pressure at any other point in the expansion curves. It is most frequently taken from the end of the stroke, the pressure being ascertained by continuing the curve $h\,k$ to the line $U x_{11}$. Putting W = calculated water evaporated per hour, u = weight per cubic foot of steam due to the total pressure at end of stroke, v = the corresponding weight per cubic foot of cushioned steam, and c = proportion of cylinder capacity represented by clearance spaces, and using also part of the symbols previously named, we have

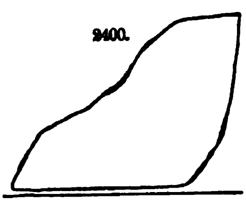
$$W = [(1 + c)u - c\,v] \times \frac{A}{144} \times 2S \times R \times 60 = .8333\,A\,S\,R\,[(1 + c)u - c\,v].$$

Except in rare instances when using superheated steam, the calculated weight of steam is less than the actual amount, on account of cylinder condensation. This condensation increases rapidly with the degree of expansion. Ordinarily 90 per cent. or more of the feed-water or water actually evaporated will be accounted for by the indicator when the steam follows about seven-eighths of the stroke; and

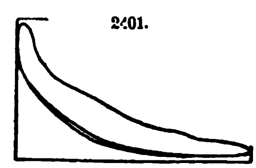
2399.



2400.



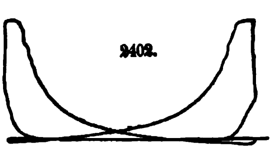
2401.



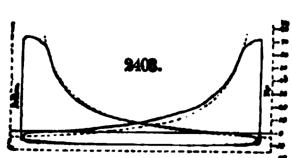
in many cases only about one-half of the actual quantity will be thus accounted for by the indicator when the steam is expanded ten times. The discrepancy varies with the quality of the steam, and all the thermal conditions under which the work is performed.

The indicator diagrams from non-condensing engines, Figs. 2399 to 2402, are reduced from a "Treatise on the Steam-Engine Indicator," by Mr. Charles T. Porter, revised by Mr. F. W. Bacon. Figs. 2399, 2400, and 2401 are from locomotives. Fig. 2399 is as near a full-stroke diagram as can be obtained with a slide-valve. It differs however from full-stroke diagrams usually obtained, from the fact that

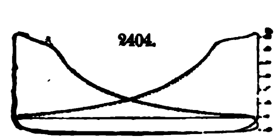
2402.



2403.

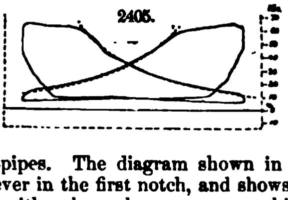


2404.

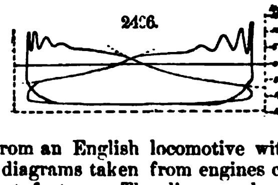


the steam-pressure at the beginning of the stroke is less than near the end, showing that the steam could not enter with sufficient rapidity to both reheat the cylinder and keep up the pressure. The diagram shown in Fig. 2400 was taken from a locomotive on the Philadelphia, Wilmington, and Baltimore Railroad, at a speed of more than 60 miles per hour, with the engine making more than 300 revolutions per minute; under which circumstances it must be considered a remarkably good diagram. The early release is necessary at such high speeds, to free the cylinder and permit the cushion to act efficiently before the return stroke. The high back pressure is necessary to secure draught with the

2405.



2406.



blast-pipes. The diagram shown in Fig. 2401 was taken from an English locomotive with reversing lever in the first notch, and shows the general shape of diagrams taken from engines cutting off short with a lap-valve, extreme cushioning being a prominent feature. The diagram shown in Fig. 2402 was taken from an engine with disengaging cut-off. The loops below the atmospheric line represent resistances against the piston, and show the common defect that the engine was insufficiently loaded to secure economy. The proper remedy is to provide more work for the engine, which will

be accomplished without extra cost for fuel. The diagrams shown in Fig. 2403 were taken from one of the vertical cylinders of the United States Coast Survey steamer Bache, at a speed too slow for economy. Water collected above the piston in such quantities as to cause the pressures at the latter part of the stroke to rise above the theoretical curve in the manner shown. Fig. 2404 represents an average diagram taken from the single vertical engine of the United States Revenue steamer Gallatin; and Figs. 2405 and 2406 represent average diagrams from the high- and low-pressure cylinders respectively of the compound engine of the United States Revenue steamer Rush.*

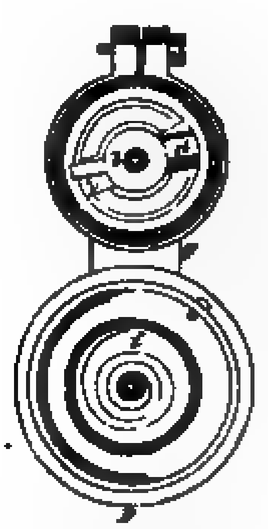
Indicator diagrams are occasionally taken with the drum operated by connection to other parts of the engine than the main piston; for instance, to the cross-head of the slide-valve, or by a cord to cause the same to revolve coincidently with the main shaft. Such diagrams are instructive to show the relative times occupied by tho admission and release of the steam, which are not shown on an ordinary diagram on account of the slow motion of the paper near the end of the stroke. They are not, however, considered of great practical utility, and are obtained chiefly as exercises, puzzles, and curiosities. Indicator diagrams have been taken on a disk rotated back and forth by the engine, the measurements being made on radial ordinates.

2407. 2408

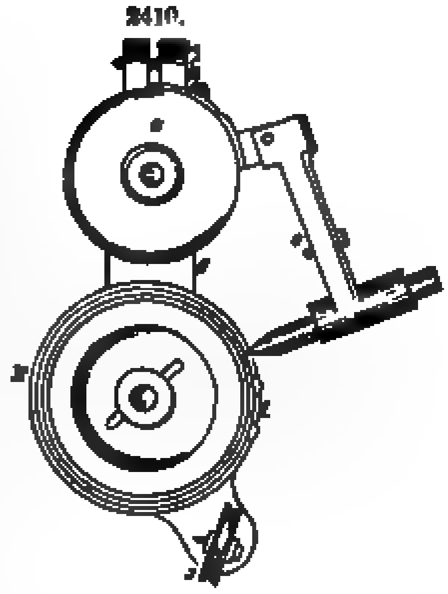
McNaught's Indicator.—Fig. 2407 is a vertical section, Fig. 2408 a vertical elevation, Fig. 2409 a horizontal section, and Fig. 2410 a plan of this instrument. This is the general form of indicator exclusively in use previous to the year 1862. The principal features will be understood from the general description in connection with Fig. 2388. The paper is wound upon the drum *E*, and held in place by a double clip-spring *l*. The drum *E* is set on an interior cylinder *F*, and a slot in the bottom of the former engages with a pin in the latter. The cylinder and drum are revolved together through a portion of a revolution in one direction by a cord secured at one end in a groove or cylinder *F*, and led over one or more guide-pulleys *f* to levers or equivalents operated by the main piston. The cylinder *F* is retracted by a coiled spring shown at the top of the bearing in Fig. 2407 The piston-rod *b* of the indicator-piston *a* carries near its middle a boss to which the free end of the spring is secured, and in which is a mortise to receive the shank of a pencil carried by *e*, which is hinged, as shown plainly in Fig. 2410, so that the pencil may be turned down upon the paper on the drum or thrown back from the same. A spring at the joint of the pencil-holder like that in a knife-handle causes the pencil to bear lightly upon the paper, or holds it back when removed.

2411.

2409.



2410.



* See discussion of the trials of revenue steamers by Mr. C. E. Emery, in the (London) *Engineering*, and in the *Journal of the Franklin Institute*, February, 1875. See also *Engineering*, vol. xxi., and *Journal of the Franklin Institute*, February, 1876.

At high speeds the weight of the reciprocating parts of the McNaught indicator prevents the piston from following promptly the changes of pressure; and the sudden admission and release of the steam induce vibration in the spring and undulations in all the lines and curves of the diagram, of such extent that the distribution of the steam is not shown satisfactorily; and the period of vibration being rarely a factor of the period in which the stroke is performed, the area of the diagram also becomes incorrect, so that the power cannot be accurately ascertained. The first attempt to remedy this difficulty was made in the Gooch indicator for use on locomotives, in which the motion of the pencil compared with that of the piston was multiplied by a lever. This enabled a stiffer spring to be used for the same scale or diagram, and the momentum of the parts was so reduced that smooth diagrams were obtained at the highest speeds. The objection was that the pencil moved in the arc of a circle, which distorted the diagram and caused difficulties in measuring it correctly.

The Richards Indicator.—The indicator now in general use was invented by Mr. Charles B. Richards of Hartford, Conn. It was first brought prominently to public notice at the International Exhibition of 1862 in London. An exterior view of the instrument is shown in Fig. 2411, and a sectional view of the cylinder in Fig. 2412. The piston has only one-fourth of the movement of the pencil, and connects to the latter through a simple parallel motion, as clearly shown in the drawing. This instrument gives accurate indications at either slow or high speeds. There are no undulations on the diagrams except at high speeds, in which case they are limited in extent and confined to the early part of the stroke. In the McNaught indicator there was difficulty in applying the pencil to the paper when the former was in motion. In the Richards instrument the parallel-motion levers are secured to the curved arms *K* attached to a sleeve turning on the case of the instrument, so that the pencil *J*, carried by the link connecting the levers, may be moved freely to and from the paper on the drum *A A*, without handling the parts in motion.

The Thompson Indicator.—This instrument, illustrated in Fig. 2413, was patented by Mr. J. W. Thompson in the year 1875. It is a modified form of the Richards or parallel-motion indicator, in which a simpler form of parallel motion is used than that applied by Mr. Richards, whereby the mass in motion is still further reduced, making it somewhat better adapted for extremely high speeds. The lever carrying the pencil is moved to and from the paper-drum by operating the handle attached to the arm as shown, and thus partially revolving the sleeve *K* on the upper part of the cylinder. The construction will be understood by examining the drawing in connection with the descriptions of the other instruments.

2413.

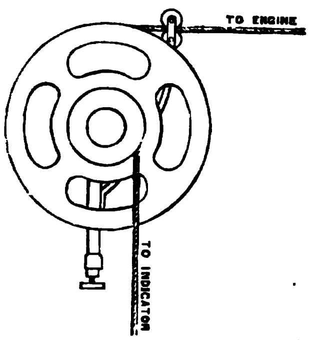
Application and Use of the Indicator.—The cocks furnished with an indicator are usually provided with screw-threads to connect with the fittings of half-inch iron pipe; and, for short connections, pipes of that size are run from the clearance spaces in the cylinders in such manner as to bring the indicator into an erect position. The connection should not be made in the cylinder passages where a current will pass the openings, nor should the opening be placed so that the piston will run over it. Both ends of the cylinder should be indicated either by the use of separate instruments, by shifting the instrument from one to the other, or by bringing the pipes together to a central T-piece to receive the instrument, with separate valves for each of the branches. When the pipes are more than one foot in length, they should be larger than half-inch; stop-valves should be provided in each branch near the cylinder, and a three-way cock at the junction. When a three-way cock is not used, the stop-cocks should be close to the T-piece, so that the double length of piece will not be filled at each stroke. In all cases the pipes should be felted, as otherwise there will be trouble with water in the indicator-cylinder, and the diagrams will rarely be accurate.

The motion is conveyed from the main piston to an indicator-drum in various ways. In condensing engines the cord is often attached directly to the air-pump levers. Engine-beams and parallel-motion levers often offer similar facilities. For large engines, used on sea and land, permanent levers are erected and kept in motion; a pin on a lever or a hook on the end of a sliding rod being arranged near the instrument for the attachment of the hook on the indicator-cord at any time. For the temporary application of the indicator, and on oscillating cylinders, a reducing wheel is used,

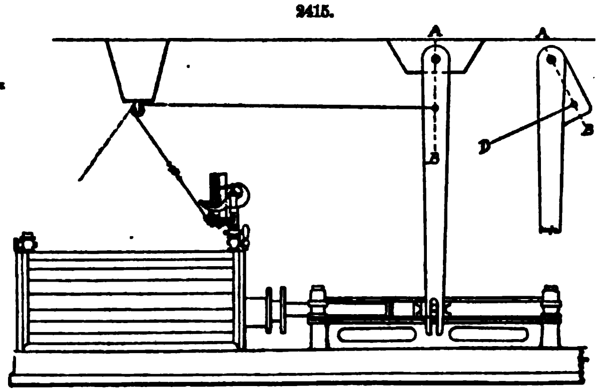
similar to that shown in Fig. 2414. A cord is attached to the engine cross-head and led back, parallel with the piston-rod (over a leading pulley when necessary), to the larger diameter of the wheel, the string being kept tight and the wheel retracted by a coiled spring inside the latter; and from a small wheel on the side of the larger one a string is led to the indicator. Rings of different sizes are sometimes provided to vary the size of the small wheel, to adapt the instrument to engines having different lengths of stroke.

To obtain the motion from the piston of a horizontal engine, it is customary to suspend a wooden lever from the ceiling, and connect it by a slot at the bottom with a bolt in the engine cross-head, as

2414.



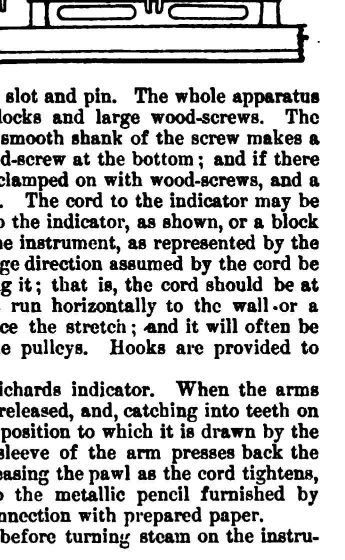
2415.



shown in Fig. 2415. A link connection may be used instead of a slot and pin. The whole apparatus can be satisfactorily constructed with soft-wood boards and blocks and large wood-screws. The broad surface of the board at the top steadies the lever, and the smooth shank of the screw makes a good bearing. The link may be connected to the lever by a wood-screw at the bottom; and if there is no satisfactory attachment to the cross-head, a block can be clamped on with wood-screws, and a screw inserted in the side of the same as a bearing for the link. The cord to the indicator may be run horizontally from a point in the fulcrum and over a pulley to the indicator, as shown, or a block secured to the side of the lever, and a cord run diagonally to the instrument, as represented by the detached view in Fig. 2415. Care should be taken that the average direction assumed by the cord be at right angles to the middle position of the lever-arm operating it; that is, the cord should be at right angles to the line $A\ B$ in Fig. 2415. Often the lever is run horizontally to the wall or a trestle. Fine wire is sometimes used instead of cord, to reduce the stretch; and it will often be advantageous to use wire for the direct portions and cord at the pulleys. Hooks are provided to disconnect the cord near the instrument.

Fig. 2416 shows in plan a detent sometimes applied to the Richards indicator. When the arms carrying the pencil are thrown back as shown, a small pawl G is released, and, catching into teeth on the bottom of the paper-drum cylinder, holds it in the extreme position to which it is drawn by the cord. Upon moving the pencil toward the drum, a cam on the sleeve of the arm presses back the pawl, thus permitting the drum to continue its motion. By releasing the pawl as the cord tightens, the drum is put in operation without jar. This figure shows also the metallic pencil furnished by Messrs. Elliot Brothers with the Richards indicator, for use in connection with prepared paper.

2416.

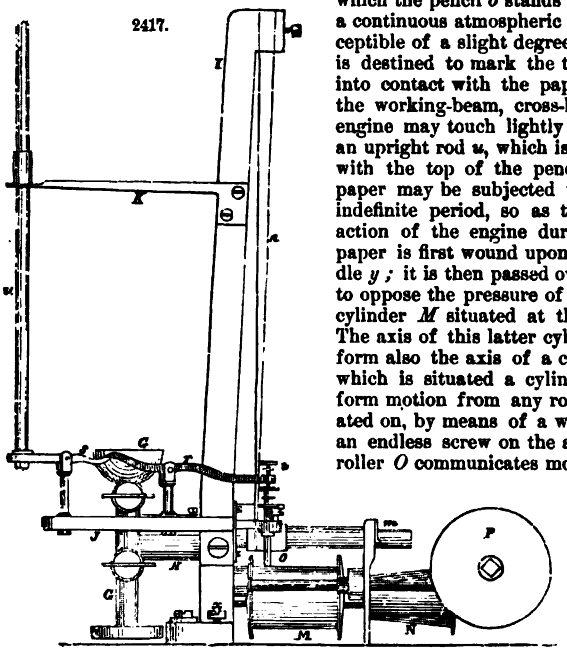


In using an indicator, the pipes should be heated if possible before turning steam on the instrument, and the piston should be permitted to work up and down for a time before applying the pencil to the paper. The atmospheric line should not be taken until after the diagram, so as to be sure that the whole instrument is thoroughly heated. The atmospheric line will be below its true position if taken before the indicator spring is heated. The speed of the engine while the indicator is in use should be accurately ascertained. If a counter is attached, it is better to note its reading before taking the diagram, and again afterward; or the revolutions may be counted while inspecting the second-hand of a watch. If the count be commenced on the even minute, the last number counted before the minute expires is the correct one. The steam-pressure, vacuum, and other customary data should also be noted on the diagram in connection with the date and hour.

Morin's Continuous Indicator.—This is an early example of a class of devices designed to obtain a record of the pressure in a steam-cylinder for a considerable length of time. Fig. 2417 is a side elevation, Fig. 2418 an end elevation, and Fig. 2419 a plan of the apparatus. G is a cock in a pipe connecting with the steam-cylinder. H is the indicator-cylinder arranged horizontally, in which a solid piston is accurately fitted to work steam-tight. Near the middle of the piston-rod m, which is properly guided in a rectilinear course, is inserted the lower end of a long parabolic spring n, the other extremity of which is fixed to the summit of a standard I, forming part of the framework of the machine, the spring being so fitted as to admit a certain

amount of travel of the piston in both directions. The piston-rod carries also a small pencil *o*, for the purpose of tracing the different degrees of tension of the steam on the opening of the lower cock *G*. Two pencils *p p* are placed in holders fixed to the framing exactly opposite to the point at which the pencil *o* stands when the stop-cock *G* is shut, to mark a continuous atmospheric line. A third pencil *q*, which is susceptible of a slight degree of vertical motion in its socket, and is destined to mark the termination of each stroke, is brought into contact with the paper by placing the instrument so that the working-beam, cross-head, or any other rigid part of the engine may touch lightly at the end of the stroke the top of an upright rod *u*, which is connected by a system of levers *r s t* with the top of the pencil *q*. A continuous band or roll of paper may be subjected to the action of this machine for an indefinite period, so as to produce diagrams representing the action of the engine during successive strokes. The roll of paper is first wound upon the cylinder *L*, by means of the handle *y*; it is then passed over the three small rollers *v v v* placed to oppose the pressure of the pencils, and is received upon the cylinder *M* situated at the opposite end of the framing *Q Q*. The axis of this latter cylinder is produced on one side so as to form also the axis of a conical pulley or fusee *N*, opposite to which is situated a cylindrical drum *O*, which receives a uniform motion from any rotating part of the engine to be operated on, by means of a worm-wheel *w* on its axis, gearing with an endless screw on the axis of the pulley *P*. The cylindrical roller *O* communicates motion to the conical roller *N* by a cord wrapped round both, and fastened at opposite extremities of each. The object of this arrangement is to compensate for the increased surface velocity due to the increased diameter of the cylinder *M* as the paper is wound on to it, by imparting to it a proportionally retarded motion.

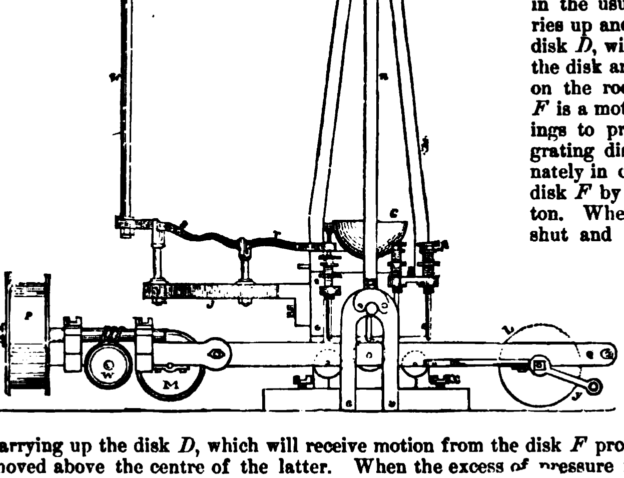
2417.



The method provided in the above apparatus for operating the band of paper from a *rotating* part of the engine will not give accurate results, as the pressures in the cylinder do not represent the rotative efforts on the crank-pin. The paper should be propelled in a series of steps, so to speak, by a motion derived from that of the main piston, as has been done in other apparatus for a similar purpose.

Ashton and Storey's Steam-Power Meter or Continuous Indicator.—A section through the case of this instrument is shown in Fig. 2420. *A* is the indicator-cylinder, the ends of which are connected to the ends of the cylinder of the engine through pipes in continuation of *a* and *b*. The indicator-piston is double-acting, and is controlled by a spring *E* in the usual way. The piston-rod carries up and down with it an integrating disk *D*, with an attached long pinion *B*, the disk and pinion being free to revolve on the rod between the collars shown. *F* is a motion-disk, adjusted in its bearings to press lightly against the integrating disk *D*. A rotary motion alternately in opposite directions is given to disk *F* by a connection to the main piston. When the cocks in connections are shut and the atmosphere admitted to both sides of the indicator-piston, the integrating disk *D* bears at the centre of the disk *F*, and receives no motion therefrom. When the connections are opened, the indicator-piston will move upward, when the excess of pressure is on the bottom, carrying up the disk *D*, which will receive motion from the disk *F* proportioned to the distance it is moved above the centre of the latter. When the excess of pressure is on the top of the indicator-piston, the disk *D* is carried below the centre of the disk *F*, and at that time the direction of the

2418.



main piston will have been reversed; so the movement of the disk F will also be reversed, and the disk D receive motion proportioned as before to its distance from the centre of F, *but in the same direction as before.* The motion of the disk D is imparted through the long pinion B to a toothed wheel C, which operates the indices of a recording apparatus not shown. The principles of the operation of integrating apparatus of this character are explained in the article DYNAMOMETERS.

2420.

A very accurate estimate of the average power developed by marine engines may be obtained by fixing the cut-off, taking indicator diagrams at intervals with different steam-pressures, ascertaining accurately the average steam-pressures by diagrams from a recording gauge (see GAUGES, STEAM), or by frequent observations of a common gauge, then calculating the average relation between the initial and mean pressures of the diagrams, and applying the same ratio to find the average mean pressure from the average steam-pressure.

SPEED-INDICATORS.—Two types of apparatus are available to indicate speed. In the first type an index shows on a scale the speed at the time, and varies its position with the velocity. This is readily accomplished by connecting the index with the slide of an ordinary conical pendulum or governor for stationary machinery, and with any of the forms of marine governor when applied to a vehicle. A common high-speed centrifugal governor, acting against the resistance of springs, is quite sufficient when care is taken to proportion the springs so that the balls and slide will take different positions at different speeds. Apparently overlooking this simple arrangement, prominent manufacturers have used a governor to operate a valve regulating a supply of water under pressure to an ordinary pressure-gauge, which thereby indicated changes of speed, but in a ratio different from the actual changes, which would not have been the case had the governor-slide been attached directly to the index and the remainder of the apparatus omitted. Speed-indicators have also been made with bent glass tubes, in which the level of the mercury was varied by centrifugal force.

In other apparatus a similar result is accomplished in a complex manner by differential mechanism, in which the difference between the speeds of the machine tested and of a timepiece varied the position of an index on the scale.

The second type of apparatus is based somewhat on the principle of the chronograph. A belt of paper is connected to move at a rate proportioned to that of the vehicle or machine, and marks are made on the same at regular intervals by electrical or mechanical connection with a timepiece, the distances between the dots representing the velocities during that period.

Wythe's Recording Speed-Indicator is designed to record the speed of trains on railroads. A band of paper on a drum is propelled by gearing connected with the axle of a car, and a pencil is traversed longitudinally of the cylinder once an hour by clockwork. A stop of the train therefore is indicated by a line parallel with the axis, and for varying speeds the inclinations of the lines vary. The strip of paper is ruled with longitudinal lines representing minutes of time, and with transverse lines representing distance—that is, miles or quarter miles. The paper has also printed on it the names of the stations at such distances as they occur according to the scale. In some cases the grades and curves are also printed on the slip. C. E. E.

INDUCTION COIL. See ELECTRIC MACHINES (STATIC).

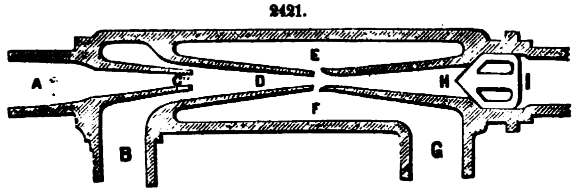
INERTIA. See DYNAMICS.

INJECTORS. An injector is an instrument used principally for forcing water into a boiler. By its agency, a gas issuing from a reservoir under a high pressure not only acquires velocity enough to carry it back again through another opening into the same reservoir, but it also transports back with it several times its weight of water. When it is considered that the steam which leaves the boiler under a high pressure with great velocity is condensed *en route*, and reënters the boiler as

water at a greatly reduced volume, the principles which govern the machine appear clear. Thus, if an opening one inch in area be made in a boiler carrying 15 lbs. pressure above the atmosphere (30 lbs. above zero), if there is no reduction by friction, the steam will issue from it with a velocity of approximately 1,440 feet a second; and the steam which would issue from this opening would be 10 cubic feet in a second, which would weigh two-thirds of a pound. When this steam is condensed to water, it maintains its velocity, but is reduced in volume from 10 cubic feet to $\frac{1}{90}$ of a cubic foot; or in other words, the stream of steam of one inch area, which issued from the boiler with a velocity of 1,440 feet a second, would be reduced to a stream of water $\frac{1}{32}$ of an inch in diameter, having the same velocity, 1,440 feet per second. The laws of hydraulics show that water will issue from a vessel under a pressure of 15 lbs. per square inch with a velocity of 45 feet per second, and that any stream having a greater velocity than 45 feet, if directed against an orifice in the vessel, would enter the vessel notwithstanding the pressure of 15 lbs. in the vessel. The jet of condensed steam has a velocity of 1,440 feet, or more than 30 times that necessary to reënter the boiler. Its velocity may be reduced by allowing it to mix with nearly 900 times its weight of water, and the mixture will still retain the velocity necessary to reënter the boiler. In the case of the injector, the same water which serves to condense the steam mingles with it and enters the boiler as the feed. These figures are reduced in practice by the friction of the sides of the orifices. The amount of water in excess which the steam can carry back is very much less than 900 times its weight in practice. This arises mainly from the friction of the jets. The friction of the sides of the discharge orifice reduces the velocity of the issuing stream to six-tenths of the theoretical velocity, and that of the receiving orifice to six-tenths of the remainder, making a total reduction to nearly one-third of the original, or about 500 feet a second, the friction of the pipes and bends reducing it still more. In practice, therefore, the velocity of the issuing steam would be 900, and of the entering stream would need to be 70 feet per second. The relative amounts of steam and water then become as $900^2 + 70^2 = 160$. The steam then may mingle with 160 times its weight of water, raising its temperature from 100° to 109°, and still retain velocity enough to force the mixture back into the boiler. If the supply of water is reduced, the entering stream becomes hotter and hotter, until a temperature is reached at which all of the steam is not condensed; at this point the injector ceases to work. The final temperature of the mixture of steam and water, at which some of the steam escapes without being condensed, is much less than 212°.

The general features which may be found in all varieties of injectors are represented in Fig. 2421, which is thus explained: "It consists of a pipe A for the admission of steam, which, escaping through the nozzle C at a high velocity, is joined by water, which, flowing in through the pipe B, and passing around the end of the nozzle C, mingles with and condenses the steam in the conical pipe D, and is driven through the pipe H and check-valve I into the boiler; excess of steam or water, from want of adjustment, escaping by the outlet E F and pipe G. The parts shown are common to all forms of injectors, under various shapes and modifications, and have been named—C, receiving-tube; D, combining-tube; H, delivery-tube; I, check-valve: E F, overflow; and G, overflow nozzle. During the passage of the water from D to H, it is driven across the space F. If too much water is being supplied to the steam, some water may escape at this point and flow out through the overflow nozzle G; while if there be too little water, air will be drawn in at G and carried into the boiler with the water."

2421.



The chief differences between the various injectors in the market consist in the relative proportions of the parts, and in the means employed for changing these proportions, either automatically or otherwise, so as to adapt the instrument to variation of steam- or water-supply. Many injectors, also, are provided with lifting attachments, to enable them to raise and deliver water from lower levels.

A series of injector trials, probably the most important and extended ever made, were conducted in May, 1879, by Park Benjamin's Scientific Expert Office of New York, with the object of obtaining new and reliable data regarding the performances of these machines expressly for the present work. Tests were made of three forms of Sellers injectors and of the Hancock inspirators, these instruments having already given notably good results under conditions of actual use. Reports of both series of trials are given in full below. The experiments were undertaken with a view to submitting the injectors to the most thorough trials that could be devised, in order to cover all conditions occurring in practice.

THE SELLERS INJECTORS.—*Report of Tests conducted by Park Benjamin's Scientific Expert Office, May, 1879, at the Works of Messrs. W. Sellers & Co., Philadelphia. Trials in charge of Richard H. Buel, C. E.*

Preparations and Conditions.—The supply-water for the injectors was delivered through a pipe in such a manner that it could be run into a tank elevated above the level of the injector into a tank below this level, or could be admitted directly to the injector under the pressure in the main, as desired. It could also be drawn directly from the pipe or through a Worthington water-meter. Both the supply and delivery pipes connected with the injector were provided with cups through which water was allowed to escape from these pipes, and in which a thermometer could be placed for the purpose of ascertaining the temperature of the feed and delivery water. The steam-supply pipe leading to the injector was provided with a throttle-valve, for the purpose of reducing the

steam-pressure when desired; and a sensitive pressure-gauge was connected to the steam-pipe between the throttle-valve and the injector. This same pressure-gauge could be connected with the delivery-pipe between the injector and the check-valve of the boiler, so that it could be used to indicate the water-pressure by closing the valve in the pipe connecting the gauge with the steam-pipe, and opening the valve in the pipe connecting the gauge with the delivery-pipe. The delivery-pipe was connected directly with the feed-pipe of the boiler that supplied steam to the injector, and there was a safety-valve in the delivery-pipe (which could be loaded to any desired pressure) between the injector and the check-valve of the boiler. A large Harrison boiler, having 48 square feet of grate-surface, and consisting of 1,088 cast-iron spheres, each 8 inches in diameter, was used to furnish steam for the experiments. The boiler was managed by an exceptionally expert fireman, who maintained the steam-pressure at any point required without sensible variation. The water-supply pipes were so arranged that by heating water in the elevated tank previously mentioned (which could be done by blowing live steam into the tank, or feeding hot water into the tank by the injector), cold water could be mixed with this in any desired proportion, in the pipe connecting the tank with the supply-pipe of the injector, so that the highest temperature of feed-water admissible could readily be determined.

A scaffolding was constructed on the roof of the testing-room, and steam, supply, and delivery pipes were provided, for connecting the injector at a considerable elevation above a portable tank in the testing-room, for experiments with lifts greater than could be measured when the injector was used on the lower level. The supply-pipe for high lifts was made in sections, so that the lift could be readily varied. A sensitive chemical thermometer was used for measuring temperatures, and this was tested by being placed in boiling water and in melting ice, and found correct at these two points. The water-meter was also carefully tested by running water through it at various rates into a tank of known capacity. It was found that the readings of the meter were somewhat in excess, the results of a number of trials at various rates giving an actual delivery of 45.4 cubic feet for a delivery as indicated by meter of 46.3 cubic feet; so that the proper correction for delivery was made by multiplying the readings of the meter, in every instance, by $\frac{45.4}{46.3} = 0.981$.

The Injectors.—Three patterns of injectors were tried in these experiments, and descriptions of each, with results obtained, are appended. All the injectors had the same numerical size, No. 6, the number indicating that the smallest diameter of the delivery tube was 6 millimetres or 0.2362 inch. This dimension was carefully measured in the case of each injector.

The general features of the injectors used in these experiments cover, with the exception of special details of construction, nearly all the varieties in the market; illustrating—

1. The injector with automatic adjustment of combining-tube and water-supply, in connection with a lifting attachment;
2. The non-adjustable injector with fixed nozzles, non-lifting;
3. The non-adjustable injector with fixed nozzles, in connection with a lifting attachment.

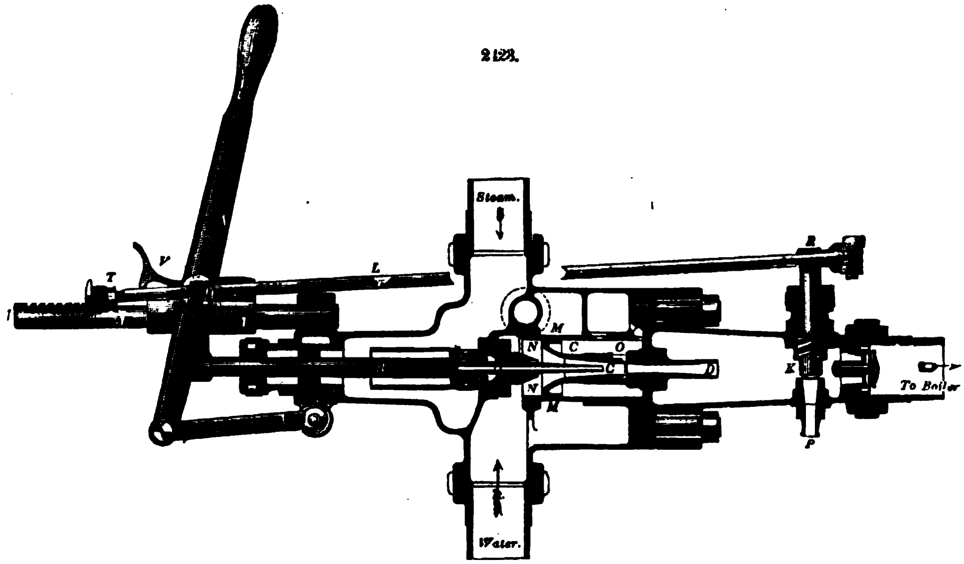
These instruments have, however, some special details of construction, as will appear by the descriptions that follow.

1. *The Self-Adjusting* 1876 *Injector.*—An elevation of this injector is shown in Fig. 2422, and a sectional view in Fig. 2423. The injector is self-contained; or in other words, it has both steam and check valves, so that it can be connected directly without other fittings, although of course it is

generally desirable to place another stop-valve in the steam-pipe, and a check-valve in the delivery-pipe, so that the injector can be taken to pieces or disconnected at any time. Another important feature of this injector is, that it is operated by a single handle, and that the waste-valve is only open at the instant of starting.

Referring to Fig. 2423, *A* is the receiving-tube, which can be closed to the admission of steam by the valve *X*. A hollow spindle passing through the receiving-tube into the combining-tube is secured to the rod *B*, and the valve *X* is fitted to this spindle in such a way that the latter can be moved a slight distance (until the stop shown in the figure engages with valve *X*) without raising the valve *X* from its seat. A second valve *W*, secured to the rod *B*, has its seat in the upper side of the valve *X*, so that it can be opened (thus admitting steam to the centre of the spindle) with-

2423.



out raising the valve *X* from its seat, if the rod *B* is not drawn out any farther, after the stop on the hollow spindle comes in contact with the valve *X*. *D* is the delivery-tube, *O* an overflow opening into space *C*, *K* the check-valve in delivery-pipe, and *P R* the waste-valve. The upper end of the combining-tube has a piston *N N* attached to it, capable of moving freely in a cylindrical portion of the shell *M M*, and the lower end of the combining-tube slides in a cylindrical guide formed in the upper end of the delivery-tube.

The rod *B* is connected to a cross-head which is fitted over the guide-rod *J*, and a lever *H* is secured to the cross-head. A rod *L* attached to a lever on the top end of the screw waste-valve passes through an eye that is secured to the lever *H;* and stops *T*, *Q* control the motion of this rod, so that the waste-valve is closed when the lever *H* has its extreme outward throw, and is opened when the lever is thrown in so as to close the steam-valve *X*, while the lever can be moved between the positions of the stops *P*, *Q* without affecting the waste-valve. A latch *V* is thrown into action with teeth cut in the upper side of the guide-rod *J*, when the lever *H* is drawn out to its full extent and then moved back; and this click is raised out of action as soon as it has been moved in far enough to pass the last tooth on the rod *J*. An air-vessel is arranged in the body of the instrument, as shown in the figure, for the purpose of securing a continuous jet when the injector and its connections are exposed to shocks, especially such as occur in the use of the instrument on locomotives.

The manipulation required to start the injector is exceedingly simple—much more so in practice, indeed, than it can be rendered in description. Moving the lever *H* until contact takes place between valve *X* and stop on hollow spindle, which can be felt by the hand upon the lever, steam is admitted to the centre of the spindle, and, expanding as it passes into the delivery-tube *D* and waste-orifice *P*, lifts the water through the supply-pipe into the combining-tube around the hollow spindle, acting after the manner of an ejector or steam-siphon. As soon as solid water issues through the waste-orifice *P*, the handle *H* may be drawn out to its full extent, opening the steam-valve *X* and closing the waste-valve, when the action of the injector will be continuous as long as steam and water are supplied to it.

To regulate the amount of water delivered, it is necessary only to move in the lever *H* until the click engages any of the teeth on the rod *J*, thus diminishing the steam-supply, as the water-supply is self-regulating. If too much water is delivered, some of it will escape through *O* into *C*, and, pressing on the piston *N N*, will move the combining-tube away from the delivery-tube, thus throttling the water-supply; and if sufficient water is not admitted, a partial vacuum will be formed in *C*, and the unbalanced pressure on the upper side of the piston *N N* will move the combining-tube toward the delivery-tube, thus enlarging the orifice for the admission of water. From this it is evident that the injector, once started, will continue to work without any further adjustment, delivering all its water to

the boiler, the waste-valve being kept shut. By placing the hand on the starting-lever, it is easy to tell whether or not the injector is working; and if desired, the waste-valve can be opened momentarily by pushing the rod *L*, a knob on the end being provided for the purpose.

Experiments with the Self-Adjusting 1876 *Injector.*—In the experiments made with the injector described above, a No. 6 instrument was employed, selected at random from a lot in stock. It was run for considerable intervals of time at pressures varying by 10 lbs. from 10 to 150 lbs. per square inch, the manipulation described above being observed in each instance; and at all pressures the adjustment of the water-supply was perfect for all positions of the starting-lever, within the capacity of the instrument.

Table I. shows the results of the experiments on delivery of injector, temperature of delivered water, and other particulars, which are fully detailed in the general heading and in the several columns. For each pressure of steam noted in column 1, the water was delivered by the injector into the boiler under approximately the same pressure. The delivery was measured by observing the indications of a water-meter, and correcting the readings as already described, meter-readings being taken at frequent intervals, and each experiment being continued for a sufficient length of time to obtain a number of duplicate readings for equal intervals. The pressures in column 8 were obtained by throttling the steam supplied to the injector, and observing the pressure at which it ceased to work, each experiment being repeated several times with precisely the same results. The temperatures in column 9 were obtained by gradually heating the water supplied to the injector, and noting the temperature at which it ceased to operate, each temperature recorded being checked by several repetitions of the experiment.

TABLE I.—*Maximum and Minimum Delivery of the Self-adjusting* 1876 *Injector, No.* 6; *Temperature of delivered Water, Pressure against which Injector delivers Water, and highest Temperature admissible of Feed. Water flowing to Injector under* 15 *Inches Head. Waste-Valve shut.*

Pressure of Steam supplied to Injector, and Pressure against which Water is delivered. Lbs. per Sq. In.	DELIVERY IN CUBIC FEET PER HOUR.			TEMPERATURE, FAHRENHEIT DEGS.			Pressure of Steam required to deliver Water against Pressure in Column 1.	Highest Temperature admissible of Feed-Water, Fahrenheit Degrees.
					DELIVERED WATER.			
	Maximum.	Minimum.	Ratio of Minimum to Maximum Delivery.	Feed-Water.	At Maximum Delivery.	At Minimum Delivery.		
1	2	3	4	5	6	7	8	9
10	75.8	63.6	0.845	66	100	94	8	182
20	82.4	61.2	0.743	66	108	104	9	184
30	94.2	56.5	0.600	66	114	116	16	184
40	100.1	60.0	0.599	66	120	123	22	182
50	108.3	64.7	0.597	66	124	125	27	181
60	116.5	63.6	0.546	66	127	138	34	180
70	124.8	63.6	0.510	67	130	142	40	180
80	133.0	67.1	0.505	66	134	144	46	181
90	141.3	69.5	0.492	67	136	148	52	182
100	147.2	64.7	0.456	66	140	159	58	182
110	153.0	67.1	0.439	67	144	162	63	182
120	156.6	73.0	0.466	67	148	162	69	184
130	161.2	74.2	0.460	66	150	165	75	180
140	166.0	78.9	0.476	66	153	166	81	126
150	170.7	70.6	0.414	66	157	167	88	121

Table II. shows the performance of the injector when lifting water 5 feet. The injector, as ordinarily constructed for use with high-pressure steam, has a spindle with a hole which is rather too small for low pressures; so that a spindle with a larger opening was attached in all but the last experiment, when the high-pressure spindle was replaced. The low-pressure spindle was such as is fitted in injectors designed for use on steamboats and other places where the pressure is ordinarily less than that carried in locomotive boilers.

TABLE II.—*Maximum and Minimum Delivery of the Self-adjusting* 1876 *Injector, No.* 6; *Temperature of delivered Water, and Pressure against which Injector delivers Water. Feed-Water lifted* 5 *Feet. Waste-Valve closed.*

Pressure of Steam supplied to Injector, and Pressure against which Water is delivered. Lbs. per Sq. In.	DELIVERY IN CUBIC FEET PER HOUR.			TEMPERATURE, FAHRENHEIT DEGREES.			Pressure of Steam required to deliver Water against Pressure in Column 1.
					DELIVERED WATER.		
	Maximum.	Minimum.	Ratio of Minimum to Maximum Delivery.	Feed-Water.	At Maximum Delivery.	At Minimum Delivery.	
1	2	3	4	5	6	7	8
30	84.8	53.0	0.625	68	123	124	16
60	114.2	67.1	0.559	68	130	134	34
90	137.7	65.9	0.479	68	139	152	51
120	150.7	77.7	0.516	68	149	156	70
150	150.7	88.3	0.586	68	170	160	97

To obtain the vacuum in the supply-pipe, as recorded in Table III., a short supply-pipe was used, having a vacuum gauge connected to it, a globe-valve at the lower end of the pipe being immersed in a tank of water, so that the injector and supply-pipe could be heated by blowing steam through the supply-pipe, and could be cooled quickly to ordinary temperature by allowing the injector to draw water from the tank.

TABLE III.—*Vacuum in the Supply-Pipe of the Self-adjusting* 1876 *Injector, No.* 6.

Pressure of Steam supplied to Injector. Lbs. per Sq. In.	VACUUM IN SUPPLY-PIPE—INCHES OF MERCURY. INJECTOR FITTED WITH SPINDLE HAVING LARGE HOLE. Injector at Ordinary Temperature.	INJECTOR FITTED WITH SPINDLE HAVING LARGE HOLE. Injector and Supply-Pipe as Hot as the Steam can make them.	INJECTOR FITTED WITH SPINDLE HAVING SMALL HOLE. Injector at Ordinary Temperature.	INJECTOR FITTED WITH SPINDLE HAVING SMALL HOLE. Injector and Supply-Pipe as Hot as the Steam can make them.
1	2	3	4	5
20	1	2¼	...	..
30	4	1¼	2	..
40	11	5	3	5
50	12	6¼	8¼	5
60	15	7¼	5¼	4½
70	19¾	7¼	6¼	4½
80	20¼	8¼	7¼	5
90	20	7¼	8¼	5
100	20¼	4	9¼	5¼
110	19¼	3	10¼	5¼
120	19¼	6	11	6
130	...	..	12¼	6¼
140	...	..	13¼	6¼
150	...	..	19	7

Experiments were then made to determine the steam-pressure required to lift water and start the injector, for such lifts as could conveniently be obtained in the testing-room, by throttling the steam until the lowest pressure at which the injector would start was ascertained. Using the high-pressure spindle, the pressure required for a lift of 3 ft. 4 in. was 33 lbs. per square inch; and for a lift of 5 ft., 47 lbs. per square inch. Lifting with this pressure, the injector delivered water against a pressure of 75 lbs. per square inch.

Having started the injector with a pressure of 47 lbs. per square inch and a lift of 5 ft., the steam-pressure was gradually reduced, and the injector continued to deliver water until the steam-pressure was 10 lbs. per square inch, the water-pressure being 17 lbs. per square inch. Using the low-pressure spindle with larger hole, the steam-pressure required for a lift of 5 ft. was 30 lbs. per square inch. The injector and supply-pipe were then heated by blowing steam into the tank, and, with a steam-pressure of 150 lbs. per square inch and a lift of 4 ft., the injector was started in 3 seconds from the time of touching the starting-lever.

Lifting water 5 ft., the highest temperature of supply-water with which the injector would start was as follows: With the high-pressure spindle and a steam-pressure of 120 lbs. per square inch, highest temperature of supply-water, 123°; 90 lbs., 130°; 60 lbs., 129°; and using the low-pressure spindle, at a steam-pressure of 30 lbs., 101°.

Experiments on the least pressure with which the injector would start, the water flowing to it under 15 inches head, resulted as follows:

With a free discharge through safety-valve in delivery-pipe, equivalent to a water-pressure of 5 lbs. per square inch, the least steam-pressure with which the injector would start was 7 lbs. per square inch.

Discharging into the boiler against a pressure equal to that of the steam, the least steam-pressure with which the injector would start was 8 lbs. per square inch.

When the injector was started, delivering water against a pressure of 5 lbs. per square inch, the steam-pressure was reduced by throttling to one half pound per square inch before the injector ceased to work.

Lifting 5 ft. with a steam-pressure of 120 lbs. per square inch, and a supply-pipe having one end free, the supply-pipe was violently shaken for the purpose of stopping the injector if possible. It was found that this could be done, but only by a peculiar shock of great violence—much more violent, in fact, than would ever be likely to occur in practice.

Finally, the amount of water wasted in starting the injector was carefully measured, the average of a number of trials being 36 cubic inches, or about 1¼ U. S. pint.

2. *The Non-Adjustable Injector with fixed Nozzles, non-lifting*, Figs. 2424 and 2425.—The No. 6 injector of this variety with which experiments were made looks externally like a cylindrical casting, open at one end for connection with the steam, with two openings in the shell on opposite sides for connection with supply and delivery pipes, and a waste-valve which can be turned radially so as to discharge in any desired direction, and can be shifted so as to discharge on either side of the shell. There is a cap on the other end of the shell, and when this is removed the delivery and combining tubes can be drawn out for examination. The external diameter of this injector is 70 millimetres, or 2.8 in., and the total length 219.5 millimetres, or 8.6 in. It is apparently about as compact as such an instrument can well be made. Indeed, considering the appearance of injectors as ordinarily constructed, this instrument might readily be mistaken for a steam-fitting. In its action, however, as will be seen by reference to Table IV., it compares very favorably with larger and more com-

plicated injectors. This injector, being non-adjustable, and having no valves attached to it, requires a check-valve in the delivery-pipe, a steam-stop valve, and a valve to regulate the amount of water supplied. The latter valve is necessary, because this injector, like all others having fixed nozzles, if not supplied with the proper amount of water for the steam-pressure under which it is working, will leak at the waste-valve when the water-supply is too great, and will draw in air if the water-supply is insufficient. This was fully proved by experiments in which, the injector being adjusted for maximum delivery under one pressure, the pressure was then varied, with the results just noted. It will be observed in Table IV. that the experiments on minimum delivery were made under two conditions in several instances—with the waste-valve both open and closed. In ordinary practice, where the steam-pressure is not maintained sensibly constant, it is not considered desirable to work the injector with the waste-valve closed.

Table IV.—*Maximum and Minimum Delivery of the Fixed-Nozzle, Non-lifting Injector, No. 6; Temperature of delivered Water, Pressure against which Injector delivers Water, and Highest Temperature admissible of Feed-Water. Water flowing to Injector under 15 Inches Head.*

Pressure of Steam supplied to Injector, and Pressure against which Water is delivered. Lbs. per Sq. In.	Delivery in Cubic Feet per Hour.					Temperature, Fahrenheit Degrees.				Pressure of Steam required to deliver Water against Pressure in Column 1	Highest Temperature admissible of Feed-Water, Fahrenheit Degrees.		Combining Tube used.
	Maximum. Waste-Valve open.	Minimum.		Ratio of Minimum to Maximum Delivery		Feed-Water.	Delivered Water.						
							At Maximum Delivery.	At Minimum Delivery.					
		Waste-Valve open.	Waste-Valve closed.	Waste-Valve open.	Waste-Valve closed during Minimum Delivery.			Waste-Valve open.	Waste-Valve closed.		Waste-Valve open.	Waste-Valve closed.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	63.6	21.8	...	0.335	.....	60	106	167	...	8	...	110	Low Pressure.
40	101.2	30.6	....	0.302	.....	63	116	206	...	23	...	144	"
[illegible]	124.6	49.8	34.1	0.357	0.273	62	[illegible]	203	230	40	139	152	"
100	101.2	68.3	....	0.675	...	60	163	207	...	50	92	133	"
[illegible]	143.6	[illegible]	51.3	0.443	0.361	60	134	205	235	40	112	151	High Pressure.
120	157.7	75.3	61.2	0.478	0.383	63	143	210	237	73	103	150	"
[illegible]	120.1	90.9	66.8	0.736	0.529	60	166	199	241	99	90	144	"

The manipulation of this injector, although not as simple as that of the "1876" instrument, presents no especial difficulty. It is necessary to open the water-supply valve sufficiently to deliver about the maximum amount of water that the injector can take at the given pressure, and, the waste-valve being open, as soon as the water escapes freely through the waste-orifice, to open the steam-valve slightly, until the jet is established, and then to open the steam-valve wide, by a quick motion. A special valve is provided, as illustrated in Fig. 2427, for facilitating this manipulation.

Another important difference between the injector with fixed nozzles and the self-adjusting injector is illustrated by comparing the maximum delivery of the two injectors, at different steam-pressures, as recorded in column 2 of Tables I. and IV. respectively. It will be seen that the maximum delivery of the self-adjusting injector increases continually with increase of steam-pressure, while the fixed-nozzle injector has a maximum delivery at a steam-pressure depending upon the proportions of the

combining-tube, which is greater than the maximum delivery for any other steam-pressure, either higher or lower. Thus, it appears from Table IV. that, using a combining-tube adapted for a pressure of 70 lbs. per sq. in., the greatest amount of water is delivered by the injector at this pressure; and that on replacing this combining-tube by one adapted to a steam-pressure of 120 lbs. per sq. in., similar results are obtained—the amount of water delivered by the injector, in each instance, decreasing as the steam-pressure is increased beyond the point for which the combining-tube is proportioned. This is true of all injectors with fixed nozzles, so that the self-adjusting injector possesses advantages apart from the ease with which it adapts itself to varying steam-pressure and water-supply. Still, there are many localities where injectors can be worked under practically constant conditions, and for such situations the non-adjustable injector is well adapted; while the simplicity of this particular form, and the ease with which its internal parts can be examined and removed, will doubtless prove strong recommendations.

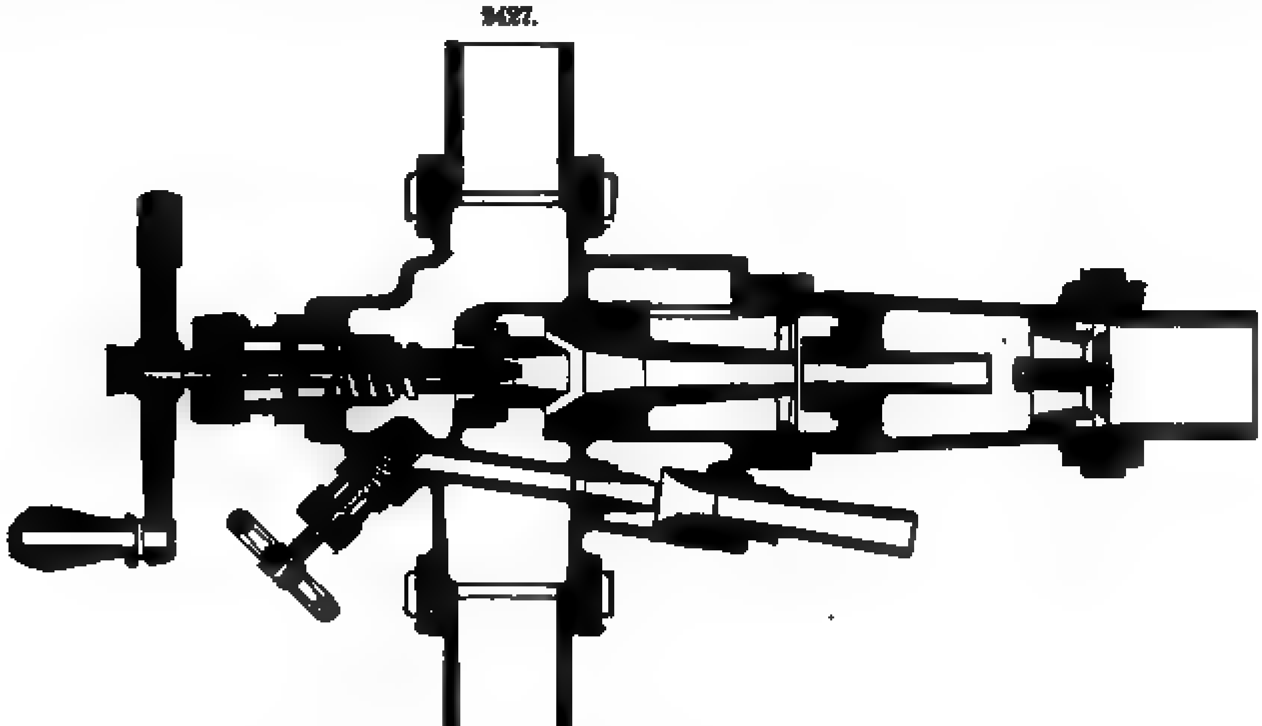
Although this injector has no lifting attachment, it can be made to lift water when once started under a head in the supply-pipe. This was illustrated by starting the injector with a steam-pressure of 22 lbs. per sq. in., the water flowing to it under 15 inches head, and then suddenly changing the connections so that the supply was obtained from the lower tank with a lift of 3 ft., the injector con-

2426.

tinuing to deliver water under these conditions. This action is probably the same as that of a siphon, which will continue to work when once charged, but cannot start unless the pipe is first filled. There being a vacuum at some point of the delivery-tube when the jet is established and the injector is at work, this acts in a similar manner to the long leg of an ordinary siphon, and the flow continues.

3. *The Non-Adjustable Injector, with fixed Nozzles, in connection with a Lifting Attachment*, Figs.

2427.



2426 and 2427.—Attached to one side of this injector is an ejector or steam-siphon which draws water, when lifted by the admission of steam, through the combining-tube, and discharges it through the orifice of the lifting attachment, through which also the waste-overflow takes place. This injector

has a check-valve connected to it, also a steam-stop valve which can be opened wide by half a revolution of the lever on the stem. In connecting the injector, since it has fixed nozzles, a water-supply valve must be provided, and, as already remarked, a second check-valve in the delivery-pipe and another steam-stop valve are desirable.

In starting this injector, steam is first admitted to the lifting-nozzle, the water-supply valve being adjusted so as to deliver about the maximum amount of water corresponding to the steam-pressure; and as soon as solid water issues from the lifting-nozzle, the steam-valve is to be opened slightly until the jet is established, when the full steam-pressure is to be admitted, and the valve that admits steam to the lifting-nozzle is to be closed.

Some little dexterity is required to start the injector for a maximum lift, but the manipulation is readily acquired. As the velocity of steam escaping from an orifice varies greatly with the pressure, other things being equal, the lifting-nozzle must have proportions depending on the minimum steam-pressure to be employed, since it can readily be adapted to higher pressures by partially closing the steam-admission valve. The lifting-nozzle on the injector with which the following experiments were made was proportioned for a minimum steam-pressure of 60 lbs. per sq. in.; and it was found that the results obtained at that pressure were not materially exceeded at higher steam-pressures, while there was a rapid decrease in the vacuum and lift for steam-pressures below 60 lbs. per sq. in.

Table V. shows the vacuum indicated on a gauge connected to the supply-pipe at different steam-pressures, the experiments being conducted similarly to those made with the "1876" injector.

TABLE V.—*Vacuum in Supply-Pipe of the Fixed-Nozzle Lifting Injector, No. 6.*

Pressure of Steam Supplied to Injector. Lbs. per Square Inch.	VACUUM IN SUPPLY-PIPE—INCHES OF MERCURY.	
	Injector at Ordinary Temperature.	Injector and Supply-Pipe as Hot as the Steam can make them.
30	7	$7\frac{1}{4}$
60	$24\frac{3}{8}$	$24\frac{1}{8}$
90	$2\ \frac{1}{8}$	$2\frac{1}{8}$
120	24	24
150	24	23

It is considered by some that the indications of a vacuum-gauge connected to the supply-pipe of an injector represent the actual lift that can be obtained. The experiments made with this injector, however, do not confirm this opinion. For the purpose of ascertaining the maximum lift, the injector was connected at the top of the scaffolding to which reference has been made, and the heights to which water could be lifted and delivered were carefully measured, the lifts being varied by changing the length of the supply-pipe, the boiler-pressure being also varied for each lift, until a steam-pressure was reached at which the injector would raise and deliver the water. The results of these experiments are contained in Table VI. It will be seen that no advantage was derived from increasing the steam-pressure beyond 60 lbs. per sq. in., while the decrease in lift was rapidly accelerated as the steam-pressure was reduced. It is believed there were no leaks in the supply-pipe used in these experiments, but the greatest lift obtained is by no means an equivalent for the best vacuum recorded in Table V. This suggests that records of lifts based on the indications of a vacuum-gauge may not be very reliable.

TABLE VI.—*Steam-Pressure required to lift and deliver Water with the Fixed-Nozzle Lifting Injector, No. 6.*

Height Water is lifted.	Steam-Pressure required to lift and deliver Water.	Height Water is lifted.	Steam-Pressure required to lift and deliver Water.
Feet. Inches.	Lbs. per Square Inch.	Feet. Inches.	Lbs. per Square Inch.
3 0	25	21 8	52
5 0	30	22 10	60
11 6	40		70
15 0	49		100

On the completion of the experiments just described, the lifting-nozzle was replaced by one adapted to a lower steam-pressure, and the injector was started with a steam-pressure of 49 lbs. per square inch, and a lift of 21 ft. 10 in.; after which the steam was throttled, the water-pressure being similarly reduced, the injector continuing to work until the steam-pressure was reduced to 7 lbs. per square inch, the water-pressure being 10 lbs. From this it will be seen that by the aid of a priming attachment the injector could be started at a much lower steam-pressure than that for which the lifting-nozzle is adapted

Duty of Sellers Injectors.—A final note in relation to the duty of injectors, or the foot-pounds of useful work performed by the consumption of 100 lbs. of coal in the boiler supplying steam to the injector, may be of interest. When the evaporation of the boiler is known, this duty can readily be computed from the data obtained in connection with the maximum delivery of the injector. This can be illustrated by an example, assuming the boiler evaporation at 9 lbs. of steam per lb. of coal, a result which, though rather above the average, is occasionally exceeded in good practice. Using the data recorded in Table I. for the maximum delivery at a steam-pressure of 130 lbs. per sq. in., it appears that $150-66=84$ units of heat were imparted to each pound of water delivered by the injector, and, the weight of a cubic foot of water at a temperature of 66° F. being about 62.3 lbs., that the total weight of water delivered per hour was $161.2 \times 62.3 = 10{,}042.76$ lbs.; so that the total amount of heat imparted to the water per hour was $10{,}042.76 \times 84 = 843{,}591.84$ units.

The total heat above 32° in a pound of dry steam, at a pressure of 130 lbs. per sq. in., is 1,187.8 units, and the heat remaining in a pound of steam above 32°, after condensation, was 150 − 32 = 118 units; so that each pound of dry steam imparted 1187.8 − 118 = 1,069.8 units of heat to the feed-water, and the weight of dry steam required per hour was $\frac{843,591.84}{1,069.8} = 788.6$ lbs. The height of a column of water equivalent to the pressure against which the water was delivered was $\frac{144 \times 130}{62.3} =$ 300.5 ft., so that the useful work performed per hour was 10,042.76 × 300.5 = 3,017,049.38 foot-pounds. The weight of coal required to do this work, on the assumed boiler evaporation, was $\frac{788.6}{9} =$ 87.6, so that the duty of the injector, per 100 lbs. of coal, was $\frac{3,017,049.38 \times 100}{87.6} = 3,455,536$ foot-pounds.

The Hancock Inspirator.—An elaborate series of trials of this apparatus was made by Park Benjamin's Scientific Expert Office of New York, to obtain new data for the present work, at the factory of the Hancock Inspirator Company in Boston, in May, 1879. The experiments were conducted by Richard H. Buel, C. E., and the report is appended.

Report of Trials of Hancock Inspirator.

The Hancock inspirator differs in some important respects from the instruments commonly classed under the head of injectors. It consists essentially of a lifting-jet and lifting-nozzle, combined with a forcing-jet and force-nozzle or injector, steam being admitted to both of these nozzles whenever the inspirator is in operation, to deliver the supply-water to the force-nozzle, and to force it through this nozzle into the boiler. Although both the lifting- and force-nozzles are fixed, their proportion one

2429.

2428.

2430.

to the other is such that the inspirator requires no adjustment for changes in steam-pressure or water-supply, the waste-valve being kept closed while the instrument is in operation, except at the time of starting. The sectional view of the stationary inspirator, Fig. 2428, will serve to explain the action of the instrument. In this figure, *A* is the steam-supply pipe, connected to the steam-space of the

boiler; B is the water-supply pipe; and C is the feed-pipe, to which is connected an overflow or waste-pipe with waste-valve, these latter connections not being shown in the figure. D is the lifting-jet, E the lifting-nozzle, G the forcing-jet, and H the force-nozzle. This latter nozzle is somewhat analogous to the combining-tube of an ordinary injector. F and I are stop-valves, the first controlling the admission of steam to the forcing-jet, and the latter determining the course of the water delivered by the lifting-jet. The action of the inspirator can perhaps be most simply explained in connection with a description of the manipulation required to start the instrument. In the figure, the inspirator is represented in operation; but when it is not working, a steam-valve in the pipe A, not shown, is closed, as is also the valve F, while the valve I and the waste-valve are open. Opening the valve in the steam-supply pipe A, steam is admitted to the lifting-jet D, drawing water through the supply-pipe B, and discharging it through the lifting-nozzle E, valve I, waste-valve, and overflow-pipe. As soon as water issues from the overflow-pipe, the valve I is to be closed, when the supply-water will pass through the force-nozzle H, and will escape at the overflow. The valve F is then to be opened, by moving the lever K one quarter turn, and the waste-valve is to be closed, when the water lifted and delivered to the force-nozzle H will be forced into the boiler by the steam issuing from the forcing-jet G. If the water-supply is to be varied, this can be effected by partially closing a valve in the supply-pipe B, without throttling the admission of steam; or both the steam and water may be throttled if desired. In practice, however, the delivery is varied by throttling the water-supply. Whatever changes of adjustment are made, whether of steam- or water-supply valves, within the capacity of the inspirator, the instrument will continue in operation with the waste-valve closed. In this respect the inspirator differs materially from fixed-nozzle injectors, which cannot be operated with the waste closed, under the conditions recited above.

The principle of the locomotive inspirator, Figs. 2429 and 2430, is the same as that of the stationary inspirator just described, but the arrangement is such that all the operations of starting and stopping can be performed by the movement of a single lever; and the instrument is self-contained, being ready for attachment without the use of additional valves. A slight movement of the starting-lever admits steam to the lifting-jet. When water issues from the overflow, a further movement of the starting-lever closes one of the valves, thus turning the supply-water through the force-nozzle, admits steam to the forcing-jet, and closes the waste-valve, thus starting the instrument. In attaching this instrument to a locomotive, it is usual to place a "lazy-cock" in the supply-pipe, by means of which the engine-runner can control the water-supply without changing the position of the starting-lever.

In the tests made with the inspirator, both forms, as described above, were tried, the size of the instruments being No. 30, this indicating that the smallest diameter of the force-nozzle was 0.30 of an inch. This dimension was carefully checked by measurement. But one inspirator of each form, locomotive and stationary, was used in the experiments, and no changes of any kind were made in them during the trials. Some of the results of the trials are contained in Tables VII. and VIII.,

TABLE VII.—*Maximum and Minimum Delivery of the Hancock Stationary Inspirator, No. 30, lifting Water from 2 to 3 Feet; Temperature of delivered Water; Vacuum in Supply-Pipe; and relative Steam- and Water-Pressures under which Inspirator will deliver Water. Temperature of Supply-Water, 70° F.*

Pressure of Steam supplied to Inspirator, and Pressure against which Inspirator delivers Water. Lbs. per Square Inch.	DELIVERY IN CUBIC FEET PER HOUR. Maximum.	DELIVERY IN CUBIC FEET PER HOUR. Minimum, Steam-Valve wide open, and Supply throttled.	DELIVERY IN CUBIC FEET PER HOUR. Ratio of Minimum to Maximum Delivery.	TEMPERATURE OF DELIVERED WATER, FAHRENHEIT DEGREES. At Maximum Delivery.	TEMPERATURE OF DELIVERED WATER, AT MINIMUM DELIVERY. Steam-Valve wide open, and Supply throttled.	TEMPERATURE OF DELIVERED WATER, AT MINIMUM DELIVERY. Steam throttled, and Supply-Valve wide open.	Vacuum in Supply-Pipe. Inches of Mercury.	Lowest Steam-Pressure with which Inspirator will deliver Water against Pressure in Column 1. Lbs. per Sq. In.
1	2	3	4	5	6	7	8	9
15	100.1	60.5	0.604	103	...	...	4	11
20	104.6	60.8	0.581	110	...	...	14	14
40	112.2	58.1	0.478	126	184	...	24	..
60	117.9	59.8	0.508	140	192	...	25	32
80	127.1	61.1	0.481	153	188	134	25	45
100	134.4	65.5	0.480	164	218	143	25	62
120	140.1	70.9	0.506	177	227	156	24	68
140	147.2	78.1	0.531	176	194	162	22½	85
150	144.5	....	.....	191	230	168	23½	90

and the manner of obtaining the quantities in the several columns will be briefly detailed. The steam- and water-pressures were measured by gauges made by the Crosby Steam Gauge and Valve Company of Boston. These gauges were tested by their manufacturers immediately before the trial, and were certified to be correct. The temperature of delivered water was measured by a thermometer inserted in the delivery-pipe, close to the inspirator. All the thermometers used in the tests were made by Huddleston of Boston, and were carefully tested. In determining the temperatures at maximum and minimum delivery, the water was forced into the boiler furnishing steam to the inspirator, and the results in Table VIII. and in column 9, Table VII., were determined under the same conditions. The boiler used in the experiments was of the sectional variety, and quite small, the grate-surface being only 6.25 feet. Considerable difficulty was experienced in maintaining the steam-pressure steady when forcing water into it by the inspirator that

was being tested, so that, in the capacity experiments, the results of which will be found in columns 2 and 3, Table VII., the delivered water was run to waste, being throttled in the delivery-pipe until the water-pressure was equal to that of the steam supplied to the inspirator. The use of so small a boiler, apart from its inconvenience, was decidedly unfavorable to the performance of the inspirator, as considerable water was entrained with the steam, owing to the severe drain upon the boiler. To determine the quantity of water delivered by the inspirator, the supply-water was drawn from a tank which was supported upon platform scales, and the time required to deliver a given weight was measured by a stop-watch, the experiments being repeated several times, at each pressure, in order to check the results. The vacuum in the supply-pipe was measured by attaching a vacuum-gauge to a short supply-pipe immersed in water, and nearly closing the water-supply valve. The highest admissible temperature of supply-water was measured by a thermometer placed in the supply-pipe, close to the inspirator, the supply-water being lifted from a barrel, and its temperature being regulated by mixing hot and cold water in the supply-pipe. The accuracy of this method of trial was also checked by gradually heating the water in the barrel until a point was reached at which the inspirator would no longer work.

TABLE VIII.—*Highest Temperature admissible for Supply-Water, lifted 2 Feet, by the Hancock Stationary Inspirator, No. 30.*

Pressure of Steam supplied to Inspirator, and Pressure against which Inspirator delivers Water. Lbs. per Square Inch.	Highest Temperature of Supply-Water admissible, in Fahrenheit Degrees.	Temperature of delivered Water, when Supply-Water is at the highest admissible Temperature. Fahrenheit Degrees.	Pressure of Steam supplied to Inspirator, and Pressure against which Inspirator delivers Water. Lbs. per Square Inch.	Highest Temperature of Supply-Water admissible, in Fahrenheit Degrees.	Temperature of delivered Water, when Supply-Water is at the highest admissible Temperature. Fahrenheit Degrees.
1	2	3	1	2	3
15	130	170	90	142	250
20	134	175	100	142	246
30	142	174	110	142	264
40	142	212	120	142	262
50	143	222	130	142	276
60	143	236	140	143	272
80	143	240	150	144	280

In some further trials of this inspirator, on June 11 and 12, 1879, lifting-jets and nozzles of different proportions were used, with the following results: At a steam-pressure of 50 lbs. per square inch, the maximum temperature of supply-water admissible was 151°; at 60 lbs., 146°; 80 lbs., 147°; 90 lbs., 145°; 100 lbs., 143°; 110 lbs., 144°; 120 lbs., 146°. Experiments were also made at different rates of delivery; and it was found that the maximum temperature admissible for the supply-water was practically the same whether the inspirator was working with a minimum or maximum delivery.

In addition to the experiments already described, the results of which are contained in Tables VII. and VIII., other trials were made, which are detailed below.

Delivering water against a pressure equal to that of the steam, the temperature of supply-water being 69°, and the lift 2 feet, the lowest pressure at which the inspirator would start was 12 lbs. per square inch with a free supply, and 9 lbs. with the supply throttled. Once started, and delivering under a free discharge, the inspirator continued to work as long as there was any indication of pressure on the steam-gauge. Delivering against a water-pressure of 5 lbs. per square inch, the inspirator continued to work until the steam-pressure was reduced to 1 lb.

Experiments were also made to determine the time in which the inspirator could be started, when both the instrument and the supply-pipe were heated by allowing steam to flow through for a short time. With the stationary inspirator, lifting water from 2 to 3 feet, allowing steam to flow through, and then starting the instrument at once, without closing the steam-valve, the time required to start was 16½ seconds when the temperature of the supply-water was 116°, and 6½ seconds when the temperature of the supply-water was 76°, the steam-pressure being 95 lbs. per square inch, and the water-pressure the same.

Using the locomotive inspirator, with a lift of 3½ feet, steam-pressure of 125 lbs. per square inch, water-pressure 160 lbs., and supply-water 70°, the time required to start, after heating the instrument and supply-pipe as hot as the steam could make them, was 2 seconds. With a lift varying between 2 and 3 feet, and a steam- and water-pressure of 95 lbs. per square inch, it was found that the inspirator would start promptly (not a single failure occurring) with supply-water heated to the highest temperature admissible for regular working. At these moderate lifts it was found that the water could be taken by the lifter, and discharged at the waste orifice, at much higher temperatures than were admissible for the operation of the inspirator—the temperature of the supply-water being raised to 195° without sensibly affecting the prompt action of the lifter.

A number of trials were made to determine the amount of water wasted in starting the locomotive inspirator, and the average was 1.15 U. S. quart.

The stationary inspirator was fitted up with a supply-pipe having considerable flexibility by reason of two right-angled bends, and attempts were made to stop the operation of the instrument by striking and jarring the supply-pipe, the steam- and water-pressure being 130 lbs. per square inch, and the lift 3 feet. After extraordinary exertions, the jet was broken in a single instance, and the inspirator stopped, but only by straining the connections to such an extent that it was considered unsafe to repeat the experiment. The supply-pipe was jarred by heavy blows applied at various points, without affecting the operation of the inspirator.

The results of the experiments in Table VII. show that the inspirator requires no adjustment for changes in steam-pressure and water-supply; and a further experiment was made by simultaneously reducing the steam- and water-pressure from 150 to 2½ lbs. per square inch, keeping the waste-valve closed, without adjusting either the steam- or water-supply. This experiment affords additional proof in regard to the adaptability of the instrument to varying conditions of pressure.

After completing the experiments already described, the stationary inspirator was connected 25 ft. above a tank, and was started, with a steam-pressure of 50 lbs. per square inch, delivering against an equal water-pressure. The water-pressure was then increased to 80 lbs. per square inch before the inspirator ceased to work. The temperature of the delivered water in this experiment was 156°. Again starting the inspirator at 25 ft. lift, and steam- and water-pressure of 50 lbs. per square inch, these pressures were gradually reduced, and the inspirator continued to operate as long as there was any indication of pressure in the steam-gauge, the water-pressure being 2½ lbs. per square inch.

The inspirator is sometimes used to elevate water into tanks, using the lifting-jet only. With a lift of 25½ ft., the temperature of the delivered water was only increased from 70° to 83°.

Experiments were also made upon the ease of starting the inspirator at a lift of 25 ft. With the inspirator and supply-pipe at ordinary temperature, the time required to lift the water was 10¼ seconds; and to start the instrument, the steam- and water-pressure being 50 lbs. per square inch, the time required was 21¼ seconds. The inspirator and supply-pipe were then heated by blowing through, and water was lifted in 48½ seconds. These trials, together with those made at low lifts previously detailed, show the remarkable promptness of the instrument in starting, under all conditions within its capacity.

The lifting-jet used in these experiments was proportioned for a steam-pressure of 60 lbs. per square inch; and to show the range of this jet, after the inspirator had been started on a 25 ft. lift, the steam- and water-pressure were simultaneously increased to 80 lbs. per square inch before the jet broke. Reducing the lift to 24 ft., the steam-pressure required to start against an equal water-pressure was 45 lbs. per square inch, and the range was considerably increased, the steam- and water-pressure being varied to 100 lbs. per square inch before the jet broke. With a lift of 24 ft., and steam- and water-pressure of 50 lbs. per square inch, the water in the supply-pipe was heated to 117° before the inspirator ceased to work.

On June 11, 1879, some experiments were made with a stationary inspirator, No. 20, at higher lifts than had been previously employed. The lifting-jet used was proportioned for a steam-pressure of about 60 lbs. per square inch, at a maximum lift; and the results of the trials are appended. For a lift of 26 ft. 7 in. the steam-pressure required to start the inspirator was 60 lbs. per square inch, and the time employed in starting was: From time of opening steam-valve to lifting water, 10 seconds; and from time of opening steam-valve until inspirator was in operation with a water-pressure equal to that of the steam, 38 seconds. After the inspirator was started the water-pressure was increased to 95 lbs. per square inch, the steam-pressure being 60 lbs., before the jet broke. The lift was then increased to 27 ft., and the inspirator lifted water in 11 seconds with 63 lbs. of steam, and delivered water against a pressure equal to that of the steam in 52¾ seconds. The water-pressure was then increased to 95 lbs. per square inch before the jet broke; and to show the range of this particular lifting-jet, the steam- and water-pressure were simultaneously reduced to 10 lbs. per square inch, and then increased to 70 lbs. before the inspirator ceased to operate.

THE INJECTOR, CONSIDERED AS A PUMPING ENGINE, is not an economical machine, as will appear from the calculations on page 169. As a boiler-feeder, however, it is more economical than a steam-pump, when cold feed-water is used, since, although but little of the heat of the steam is converted into useful work, nearly all the remainder is returned to the boiler with the feed-water. In its present improved form, the injector is rapidly superseding the pump on locomotives, and to a considerable extent on stationary and steamship boilers also.

INSULATORS. See TELEGRAPH APPARATUS.

IRONCLAD VESSELS. See ARMOR.

IRONING MACHINE. See LAUNDRY MACHINERY.

IRON-MAKING PROCESSES. The various processes of iron-making, by which is here understood the production of wrought iron from iron ore, are divided into two classes, the direct and the indirect. The direct processes are those in which the ore is converted in one or more operations into wrought iron, without being first converted into cast iron. The indirect processes are those in which the ores are first smelted in a blast-furnace, forming pig iron or cast iron, and the pig iron is then converted by a subsequent process into wrought iron. For the method of making cast iron, see FURNACE, BLAST, and FURNACE, CUPOLA; for other subjects more or less directly related to iron-making, see FORGE, FORGING, FURNACES, HAMMERS, PUNCHING AND SHEARING MACHINERY, and STEEL.

In the blast-furnace, iron ores—containing oxygen in combination with the iron, together with various earthy impurities—are first deoxidized, and the impurities are then removed by fluxing. The iron is then impregnated with from 2 to 5 per cent. of carbon, a smaller percentage usually of silicon, and still smaller percentages or traces of other impurities, as sulphur and phosphorus; then melted and run out of the furnace in the shape of pig iron. In the subsequent conversion of pig iron into wrought iron, the carbon, silicon, and other impurities are removed, and the resulting product, wrought iron (sometimes called malleable iron, also weld iron), consists of iron with very small proportions of impurities. The methods by which this conversion is accomplished include what are known as the finery and the puddling processes, which are treated of hereafter. By the Bessemer and Siemens-Martin steel processes pig iron is also decarbonized and freed from impurities, forming a product which may be as pure as or even purer than wrought iron, to which the names of mild steel, homogeneous metal, and ingot iron are variously applied.

In this article the several direct processes will be described, also those indirect processes whose

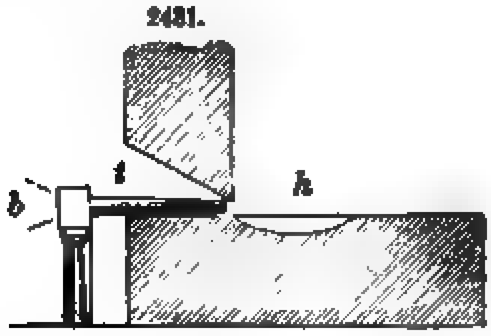
object is the conversion of pig into wrought (weld) iron. Those indirect processes, including the Bessemer and Siemens-Martin processes, whose object is the conversion of pig iron into mild steel (ingot iron) are treated of in the article on STEEL.

I. DIRECT PROCESSES.

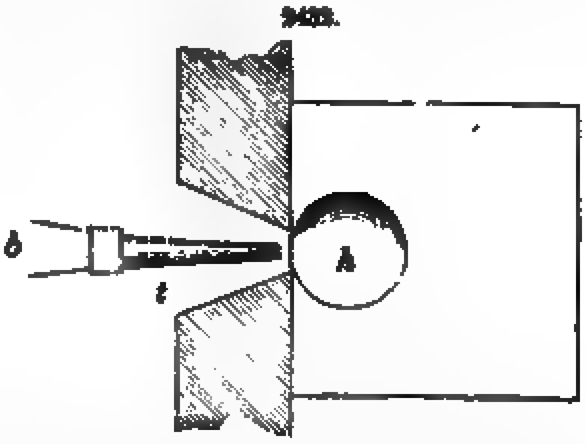
The direct processes of making wrought iron are both ancient and primitive. Records of these processes date back to the earliest historical times, and processes almost exactly similar to the ancient ones are still in use in uncivilized countries, and to a small extent, for the manufacture of iron of certain grades, in the United States. The direct processes have been almost entirely superseded in modern times by the indirect; not however on account of the improved quality of the product of the latter, but on account of its cheapness. In recent times many efforts have been made so to improve the economy of the direct processes that they may make iron more cheaply than the indirect, but thus far without success, except under the most favorable conditions in a very few instances.

In the most primitive processes, such as those which are still used in Asia and Africa, scarcely any other apparatus is needed than a small hearth, or a hole in the ground, with or without a chimney. An air-blast is furnished by a bellows or other simple blowing machine. Only rich ores are used, and the fuel is invariably charcoal. A furnace of this kind, still used in Persia, consists of a mere cavity in the earth, 6 to 12 in. deep, and of a diameter equal to twice the depth. It is lined with pulverized charcoal. Charcoal in fragments is then thrown in, and covered with ore, which may be fine and caked together with water, or in coarse pieces. Several alternate layers of charcoal and ore succeed, when the whole heap is covered with charcoal. It is then fired at the bottom, and the blast applied by a large hand-bellows, which blows through a pipe introduced in the lower part. In a few hours a small ball, or *loup*, is obtained, which is taken out and hammered by hand. By reheating and hammering it is finally brought into shape, and purified of cinder. The process is such as may be practised on a smaller scale in a blacksmith's forge. Figs. 2431 and 2432 are respectively a section and a ground plan of a hearth in use in Europe about the middle of the 16th century, as described by Agricola. The letter *h* in both shows the hearth proper, *t* the tuyere, and *b* the bellows. This form is not unlike the blacksmith's forge of our own times, and the furnaces used in the

2431.



2432.



Catalan process at the present day are but modifications of it. These crude furnaces show that the production of iron from the ore is a process of the most simple description. The quality of the iron produced in them also is not surpassed, and rarely even equalled, by that made by the most approved methods of modern times. The enormous progress in iron-making during the last three hundred years, and especially within the present century, has been in the direction of quantity and cheapness, and not in that of improved quality.

The Catalan Process.—This process derives its name from the province of Catalonia, in northern Spain, where probably it was first introduced into western Europe. The furnace in which it is carried on is known as the Catalan forge, although the names open fire, forge, German forge, and bloomary are often indiscriminately applied to it. Some writers make distinctions between the various types of furnace to which these names may be correctly applied, but they are not important, and the same name is applied to different types of furnaces in different localities. The term bloomary is also applied to a furnace which, while somewhat similar in shape to the Catalan forge, is used for a different purpose, viz., the conversion of pig iron into wrought iron. It is described under the head of the finery process.

2433.

W

The simplest form of the Catalan forge, as still used in the Pyrenees, is shown in Figs. 2433, 2434, and 2435. Fig. 2433 is a vertical section through the axis of the tuyere, and Fig. 2434 another section at right angles to the former. In Fig 2433, *W W* represents the wall separating the forge from the blast machinery, and in which is the embrasure for the tuyere. The hearth is usually lined with

cast-iron plates, and the *counter*, or side opposite the tuyere, with flat bars. Sometimes the lining of these is a refractory sandstone or granite; but the cinder-slope (on the side *o* of the tuyere), on which the workman rests his bars, is always of cast iron. The aperture *o* is for the discharge of cinder into the embrasure beneath. The tuyere *t* is a truncated half cone of copper, with the orifice

2431.

or *eye* circular, from 1½ to 2 in. in diameter; it is set at about 20 in. above the bottom, and inclined at an angle of 30° to 40°, and projects about 8 in. into the fire. The hearth at the bottom measures about 24 to 26 in. square. Blast is furnished either by a bellows, or by the blowing machine driven by water-pressure known as the *trompe*. (See BLOWERS.) In the operations of the forge as usually conducted, a charge of about 1,000 lbs. of ore is weighed out and crushed under the forge-hammer. The furnace having been heated, and a mass of incandescent charcoal and melted cinder lying upon the bottom, fresh charcoal is packed in the hearth up to the orifice of the tuyere, and upon this bed a box of coarse ore is emptied and packed against the sloping side or counter, charcoal alternating with fine ore being packed on the tuyere side. The blast is started at a light pressure, gradually increasing to about 1½ lb. per square inch. The whole of the contents of the hearth, except a small portion at the sloping side on which the coarse ore is placed, are kept covered with fine ore and charcoal, thus forcing the gases (carbonic oxide) formed by the combustion of the charcoal to pass out through the coarse ore and reduce it to the metallic state. The ore gradually sinks down, and the impurities melt into slag, which is tapped off every hour. The operation lasts about six hours, at the end of which time the greater portion of the ore has been reduced and the impurities fluxed away. The pieces of reduced iron which may be adherent to the sides are pushed by the workmen into the central mass of iron. The blast is then stopped, and the mass of iron, known as a *loop* or *massé*, weighing about 350 lbs., is pried out of the fire by long bars, and hammered into blooms or billets. Four operations or heats are usually made per day. The details of the process vary to some extent in different localities. Both the quality of the product and the yield depend upon the skill of the workmen. The slag is very rich in oxide of iron, which of course causes a considerable waste of ore. According to François, in the forges of the department of Ariége, in the south of France, 100 kilogrammes of merchant iron are generally obtained from 212 kil. of ore, with a consumption of 340 kil. of charcoal. Richard estimates that in good work 100 parts by weight of ore should yield 31 of bar iron and 41 of slags containing about 30 per cent. of metallic iron. Yields obtained by Richard from the forge du Ressecq were: ore 100, bar iron 31.2, slags 50.2; ore 100, bar iron 31, slags 51.8. (For a very full account of the Catalan process, as practised on the continent of Europe, and of the still more primitive processes in use in India, Borneo, and Madagascar, consult Percy's "Metallurgy of Iron and Steel," London, 1864, pp. 254–319.)

Various modifications of the Catalan process have been made in certain localities. One of the most important improvements is the application of the waste heat to heat the blast, which has reached its greatest development in the United States. In 1878 there were 64 works with over 200 Catalan forges in the United States, with a total annual capacity of about 65,000 net tons per year. Of these, 24 works with 145 forges were in the State of New York, nearly all of them being in Clinton and Essex counties, in the Adirondack region. In 1850 there were as many as 200 forges in these two counties. At that date the capacity of each forge was about 1 ton every 24 hours; with the better quality of ores 100 lbs. per hour could be obtained. Using selected ores containing 65 per cent. metallic iron, 2¼ tons of ore were required per ton of iron made, and 250 bushels of charcoal were used per ton. At the present date this practice has not been essentially improved upon. The hearths of these forges are about 32 in. square and 18 in. deep. The sides and bottom are of cast-iron plates 2 or 3 in. thick. The fire is open at the front, but is walled in at the sides and back. The tuyere is at the side. The blast is heated to about 550° F.; the hot-blast oven, consisting of a few ∩-shaped pipes, is placed directly over the fire. The ball of iron, or loop, weighing about 300 lbs., is drawn out every three hours, eight heats being made per day. It is shingled under hammers weighing from 1 to 2 tons, and formed into slabs or billets. The iron made by the Catalan process in this country is generally of the most excellent quality, and commands a price about 50 per cent. greater than that of ordinary iron made by puddling. It is this fact which has enabled the process to continue in existence to the present time, notwithstanding its great waste of material and want of economy of labor.

The Osmund Furnace.—Percy describes a furnace which he names the osmund furnace, from the Swedish word *osmund*, the name of the bloom used in it. It is merely a Catalan furnace extended

upward in the form of a quadrangular or circular shaft. A vertical section is shown in Fig. 2436. From a perspective view given by Percy it would appear to be about 10 ft. high. It was formerly in use in Norway, Sweden, and other parts of Europe, and "it continues in use to this day" (1864), says Percy, "in Finland." The Germans called it *Blaseofen* and *Bauernofen*. It is interesting as marking a stage in the gradual development of the blast-furnace from the Catalan forge; this and the *Stückofen*, hereafter described, being the intermediate furnaces between the Catalan forge and the blast-furnace. The method of operation of the osmund furnace is nearly the same as that of the Catalan forge. The following remarks concerning it are taken from Percy: "Not more than 1½ ton could be made weekly in one of these furnaces; and in working up the osmund or bloom there was a loss of from 33 to 50 per cent. It is especially worthy of remark that, notwithstanding the presence of a large amount of phosphorus in the ore employed, the osmund furnace yielded good malleable iron; whereas the iron obtained from such ores by the usual method of producing cast iron in the first instance, and subsequently converting it into malleable iron, is cold-short and bad. It has been previously stated that the osmund furnace is still in operation in Finland; but a still more interesting circumstance is, that it maintains its ground side by side with a modern blast-furnace. The ore treated is so-called lake ore; and it is only by means of the osmund furnace that good iron can be made from this ore, the reason, no doubt, being that the phosphorus in the ore does not pass into the iron, but remains in the slag."

2436

The Stückofen.—The Stückofen, Wolfofen (from *Stück*, *Wolf*, names for the bloom), or high bloomary furnace is the final development of the old furnaces in which wrought iron was produced direct from the ore. In it, indeed, by increasing its height and the pressure of the blast, cast iron was first made, it is believed by accident; and this cast iron was then a waste product, as the art of making iron castings was at that time unknown. The Stückofen is now nearly abandoned in Europe, a few only said to be still in existence in Hungary; but a similar furnace is in use in Japan. (For description of the latter, see *Journal of the Iron and Steel Institute*, 1876, No. 2, p. 612.) According to Karsten, the European furnaces varied in height from 10 to 16 ft. In some the shaft increased regularly from top to bottom, but in most it bellied out in the middle; it was either round or quadrangular in horizontal section. One described by Percy had an interior form of two truncated cones with their broad ends or bases in contact. It was 16 ft. high; the diameter at the bottom was 2½ ft., at the top or mouth 1½ ft., and at the widest part, which was exactly in the middle, 4 ft. 2 in. The furnace was carried up a few feet higher than the mouth, gradually widening, for the sake of convenience in charging. There was one tuyere, placed 14 in. above the bottom, but in the course of long working the bottom or hearth stone became so much corroded away that it was 20 in. above the bottom. The operation of the Stückofen did not differ greatly from that of the Catalan forge. A lump of from 4 to 6 cwt. required for its production from 216 to 284 cubic feet of charcoal. On an average three such lumps were made in a day. The metal forming the lump produced in the Stückofen was described by Quantz (1799) as soft, tough, and malleable, though less so than bar iron; he considered it as intermediate between cast and bar iron, yet nearly approaching the latter.

The Stückofen was at one time employed for the production of both wrought and cast iron, the conditions necessary for the formation of the latter being prolonged contact of the reduced metal with carbon at a high temperature; and this is secured by increasing the proportion of charcoal relatively to the iron-producing materials. When the Stückofen produced cast iron, it became known as the Blauofen; and it was the development of this by increasing its dimensions, the pressure of the blast, and the temperature of the hearth, which gradually led to the blast-furnace of the present day, in which cast iron exclusively is produced. (See FURNACE, BLAST.)

Modern Direct Processes.—Soon after the introduction of the blast-furnace, malleable or wrought iron began to be made from cast iron, by various methods hereafter described. These constituted the indirect processes, which on account of their greater economy have nearly superseded the direct processes. It has been found in practice that to convert the ore into cast iron, and then to convert the cast iron into wrought iron, required a smaller expenditure per ton of product than to make the wrought iron from the ore in one operation. The manifest theoretical advantages of direct processes, however, have for many years, and especially during the last half century, led inventors to devise methods by which the direct processes could be so improved as to become more economical than the indirect. Frequently these new direct processes have seemed almost to attain commercial success, but the improvements in the indirect processes have been so rapid that the latter have more than held their ground against the former. The new direct processes are still being experimented upon by some of the most eminent metallurgists; and although they have not come into general use at the present time, it is not improbable that they may do so before many years have elapsed. A brief statement of several of the modern direct processes will therefore be of interest.

Chenot's Process.—M. Adrien Chenot of Clichy, France, in 1823 made his first trials of a process for making steel direct from the ore, and for thirty years experimented and improved upon these processes. From 1852 to 1857 several works were erected in France, Spain, and Belgium for the manufacture of steel upon a commercial scale by his methods. In 1871 the process was still in use at Clichy, near Paris, where it had been established in 1855, and near Bilbao in Spain, where it had

been established in 1852. The following is condensed from Grateau's account of the process as conducted at Hautmont, in France, in 1857, as given by Percy:

The ore sufficiently pure, if in mass, is broken into lumps of about 30 cubic centimetres (1.779 inch); but if pulverulent, it is agglutinated by compression, with the addition in some cases of reducing matters—for example, 3 per cent. of resin. It is then mixed with more wood charcoal than suffices to remove the whole of the oxygen from the ore. In practice an ore containing 55 per cent. of iron is mixed with 1¼ to 1½ time its bulk of charcoal. With this mixture the reduction furnace is charged. The furnace consists of two rectangular vertical chambers or retorts, about 6 ft. long, 1⅝ ft. wide, and 28 ft. high, inclosed in a cubical pedestal of masonwork surmounted by a truncated cone. Beneath the retorts are the fireplaces, and below the level of the ground at the bottom of the fireplaces is a pit to receive the apparatus for discharging. Around each of the retorts is a series of vertical flues, communicating below with the fireplaces, and above with a large flue opening into the air. If the reduced iron were withdrawn while hot, or even warm, it would on coming in contact with the air take fire and be again oxidized. In order to prevent this, at the bottom of the retorts is fixed a rectangular case of sheet iron, about 15 ft. in length, termed the *refroidissoir* or cooler. The cooler may when necessary be surrounded with a second case, through which circulates a current of cold water. In a furnace at Hautmont with a single retort, 4 ft. 11 in. long by 1 ft. 8 in. broad, the charge was about 1½ ton of calcined iron ore and half a ton of wood charcoal. Reduction is completed in 3 days, when the charge is withdrawn, and the freshly-formed iron sponge (the name given to the reduced metal) falls into the cooler, where it remains 3 days; and so the operation is repeated, the entire process, including reduction and cooling, lasting 6 days. The yield is about 12 cwt. of sponge, and the fuel consumption about 1 ton 6 cwt. of charcoal. When perfectly reduced, iron sponge has a bright gray color, is soft, and can be easily cut with a knife into thin slices. It may be ignited by a match, when it continues to burn until wholly oxidized. The imperfectly reduced ore has a black color, and can neither be cut nor ignited. A modification of Chenot's process consists in reducing the ore by a current of hot carbonic oxide, and not by intermixture with solid carbonaceous matter. The reduction-chamber is connected with two carbonic-oxide generators on each long side, communicating with the reducing chamber near the bottom and above the top of the cooler. After the sponge is removed from the cooler it is balled together in a charcoal hearth, and hammered into a bloom.

A report on Chenot's process made in 1856 by MM. Combes, Regnault, and Thiria to the French Minister of Public Works, says: "It is not probable that these processes, in their actual state, could be applied with advantage to the manufacture of iron, except perhaps where rich ores of iron might be procured at a low price and labor would be cheap." The French Exposition of 1855 granted the medal of honor to M. Chenot, considering his process the most important metallurgical improvement of the time.

Clay's Process.—In 1837 and 1840 Mr. William Neale Clay obtained two patents in England on a process for making wrought iron direct from the ore. In this process the purer kinds of ore were crushed to lumps not larger than a walnut, and these, mixed with one-fifth their weight of charcoal, coke, coal-slack, or other carbonaceous matter, were subjected to a bright-red heat, in a clay retort or other suitable vessel, until the ore was reduced to the metallic state. When the reduction was complete, the spongy iron was transferred direct to a puddling furnace, where it was balled, and then wrought into blooms under a tilt-hammer. The process succeeded in making an excellent quality of iron, which however was not uniform, but it was commercially a failure.

A modification of Clay's process was tried at Workington, England, which was not abandoned till after 1,000 tons of bar iron had been made by it at a heavy loss. In this modification the ore was reduced directly in a puddling furnace. A mixture of ground hematite with about one-third its weight of coal-slack, washed in a solution of soda ash or brine, was used, and smelted in conjunction with pig iron. To the mixture of hematite and slack there were added about 4 lbs. of fire-clay, 4 oz. of soda ash, and 6 oz. of common salt to each 112 lbs. of ore. The bar iron produced was tolerably uniform and of fair quality.

Renton's Process.—This process was patented in the United States by James Renton in 1851. It was carried on upon a commercial scale in Cincinnati and in Newark, N. J.; but it proved a failure in economy, although good iron was produced by it. The furnace in shape resembled an ordinary puddling furnace, having a fire-brick chamber at the end, 10 ft. high, 6 ft. broad, and 7 in. wide. This chamber, which was in fact a large vertical muffle or retort, was entirely surrounded externally by the flue or chimney of the furnace. It was filled with 12 cwt. of a carefully made mixture of from 20 to 25 per cent. of ore, and from 75 to 80 per cent. of coal, both finely broken, and became sufficiently heated to cause the reduction of the ore. The reduced ore was discharged, as required, from the bottom of the chamber into the body of the furnace, where it was exposed to a welding heat and worked into balls, which were hammered in the usual way into blooms.

Yates's Process.—Mr. Frederick Yates published a pamphlet in London in 1860, describing a proposed direct process which appears to be a modification of Chenot's. It employed gas-furnaces, in which carbonic oxide was produced in generators, to heat the reduction chamber. The latter consisted of a succession of three fire-clay retorts, set vertically over each other and united by socket-joints. They were from 30 to 35 ft. in height, and capable of holding 30 to 40 tons of ore. The shafts were filled by means of hoppers at the top, and the product was discharged through double air-tight doors at the bottom, so as to prevent the admission of air.

Smith's Process.—A direct process experimented upon at the Clifton Iron Works, New York, in 1868, the invention of Dr. George Hand Smith, is described by Osborn. The crushed ore is mixed with about half its weight of charcoal, and charged in about 2 tons at a time into a reverberatory furnace, in which also carburetted hydrogen is generated from petroleum or coal-tar. The carburetted hydrogen aids directly in reducing the ore. In about five hours the ore is deoxidized and

carbonized, so that the resulting sponge is really steel. This process, Osborn states, does not seem to have been very successful.

Another direct process, mentioned by Osborn as in operation at Ringgold, Pa., consists "in drawing the ore down from shelf to shelf to meet an ascending column of ignited charcoal particles, and thus deoxidizing the ore." There is no later record of the results of these two processes.

Still more Recent Direct Processes.—The above-described modern processes have all resulted in commercial failure, and have been nearly if not quite abandoned. As most of them, however, contain some elements of success, and the cause of their failure was generally mechanical difficulties which perhaps are not insurmountable, they may again be brought forward in improved shape. They are worthy of record, therefore, for other purposes than as mere matters of history. Four new direct processes, of which accounts have been published, have been invented, and are still (1879) being experimented upon, with apparently some prospects of success. These are the direct processes of Dr. C. W. Siemens of England, Mr. Thomas S. Blair of Pittsburgh, Mr. Charles M. Du Puy of Philadelphia, and Mr. Edward Peckham of Plattsburgh, N. Y.

Siemens's Direct Process.—This process is in operation at Towcester, England, and at Landore, Wales. The inventor first experimented at Landore in 1869 with a rotating furnace. Air and gas were admitted at one end, and the flame and gas produced by their combustion passed to the opposite or chimney end, where a mixture of crushed ore and carbonaceous material was introduced. By the slow rotation of this furnace, the mixture gradually advanced to the hotter end of the chamber, and was reduced to spongy iron. The reduction of the ore was accomplished in a comparatively short time, but it was found that the spongy metal produced absorbed sulphur from the heating gases, and thus was rendered unfit for the production of steel. This led to the abandonment of this form of the process. The next stage of the experiment consisted in melting ores mixed with fluxing materials in a reverberatory furnace so arranged as to accomplish the fusion in a continuous manner, so that the fused ore might be acted on by solid carbonaceous matter, and the metallic iron be separated in a compact form, while the earthy constituents of the ore would form a fusible slag with the fluxing material. The results proved that a most excellent character of iron could be obtained by this means, but the yield was unsatisfactory, the slags showing a variable percentage of iron, amounting rarely to less than 15 per cent., but occasionally reaching 40 per cent. The precipitation of the iron required a most intense heat, exceeding the welding heat of iron. The inventor then, in 1870–'71, again turned his attention to the rotating furnace.

2436.

The difficulty in obtaining a lining capable of resisting the high degree of heat necessary for the precipitation of the iron, and at the same time resisting the chemical action, was overcome by the use of bauxite mixed with clay and plumbago. The heat for the rotating furnace is produced by the Siemens gas-producers and regenerators (hereafter described). Fig. 2437 represents a longitudinal vertical section through the rotator and the regenerators, and Fig. 2438 a vertical cross-section through the rotator. The improved rotating chamber is constructed of iron, and rests upon four anti-friction rollers.

Wheel-gearing is applied by which either a slow rotative velocity of 4 to 5 revolutions per hour can be imparted to the chamber, or a more rapid velocity of 60 to 80 revolutions per hour. The chamber used at Landore is 7 ft. 6 in. in diameter and 9 ft. long, and is provided with a bauxite lining about 7 in. thick. A tap-hole is on the working side for discharging the slag into the cave below, where it is received into vessels mounted on wheels. At the two extremities of the rotating chamber are large orifices, one of which, on the side of the regenerators, serves for the introduction of the heated gas and air, as well as for the exit of the products of combustion, and the other, facing the working platform, is closed by a stationary door. The gases enter with a certain velocity which sends them forward toward the door, and makes them reach the exit passage only after they have traversed the rotating chamber to and fro. (*Journal of the Iron and Steel Institute*, i., 1873.)

Dr. Siemens has erected three of these rotative furnaces at his experimental works at Towcester, two of them with working drums 7 ft. in diameter and 9 ft. in length, and the third of smaller dimensions. The ends of the furnace-chamber are lined with bauxite bricks, and the circumference with ferrous oxides, resulting from a mixture of furnace-cinder enriched with roll-scale or with calcined blackband in lumps. The operation is thus described by Dr. Siemens in a paper read at the Newcastle meeting of the Iron and Steel Institute in September, 1877 (*Journal of the Iron and Steel Institute*, 1877): "About 30 cwt. of ore mixed with about 9 cwt. of small coal having been charged into the furnace, it is made to rotate slowly for about 2¼ hours, by which time the reduction of the metal should be completed, and a fluxed slag be formed of the earthy constituents containing a considerable percentage of ferrous oxide. The slag having been tapped, the heat of the furnace and the speed of rotation are increased to facilitate the formation of balls. These balls contain on an average 70 per cent. of metallic iron and 30 per cent. of cinder, and upon careful analysis it is found that the particles of iron, if entirely separated from the slag, are pure metal, although the slag may contain as much as 6 per cent. and more of phosphoric acid and from 1 to 2 per cent. of sulphur. In shingling these balls in the usual manner, the bulk of the cinder is removed, but a sufficient residue remains to impart to the fracture a dark appearance without a sign of crystalline fracture. The metal shows in being worked what appears to be red-shortness, but what should be termed slag-shortness. In piling and reheating this iron several times, this defective appearance is gradually removed, and crystalline iron of great purity and toughness is produced. The balls as they come from the rotator are placed under the shingling hammer and beaten out into flat cakes not exceeding an inch in thickness. These are cut by shears into pieces of suitable size, and formed into blooms of about 2 cwt. each, which are consolidated under a shingling hammer and rolled into bars. The bars have been sold in Staffordshire and Sheffield at prices varying from £7 to £9 per ton, being deemed equal to Swedish bar as regards toughness and purity."

The Siemens process was experimented upon in Pittsburgh for a few months in 1877–'78. While excellent iron was produced, the waste was so great as to prevent the success of the process on a commercial scale, and caused its abandonment at the time. Another furnace for working this process is now (1879) being erected at Tyrone, Pa.

Blair's Direct Process.—In 1872 Mr. Thomas S. Blair of Pittsburgh made an improvement on Chenot's and Clay's processes. The operation was conducted in an upright retort, circular in section, 4½ ft. in diameter and 50 ft. high. In the upper 10 ft. was inserted a metal pipe, or "thimble," 3½ ft. in diameter, leaving for this distance from the top an annular space about 4½ in. across, through which the ore and charcoal passed down. (Experience showed that these dimensions were too large: 3 ft. diameter of retort and 2 ft. 4 in. diameter of thimble, and a total height of 40 ft. from ground level, are large enough.) Heat produced by burning fuel-gas from any form of generator is applied outside of the retort; and the carbonic oxide rising upward in the thimble is met by air passing downward to meet it, producing a mass of flame in the thimble, keeping it at a red heat except near the top. The ore and charcoal charged into the top of the annular space are thus exposed to heat from both the outside and inside. The reduced ore is cooled in passing down to the lower portion of the retort, which is kept closed until the sponge is removed. One such retort produces about 2 tons in 24 hours. The sponge after removal is compressed by hydraulic power into blooms, which can be welded in a heating furnace or melted in an open hearth into soft steel. In melting the sponge with half as much pig iron into steel in a Siemens open-hearth furnace, the loss was about 15 per cent.

In 1876 Mr. Blair discovered during some experiments that by the addition of a small quantity of alkali to the carbonaceous matter mixed with the ore, the action of reduction was quickened to a remarkable extent, and ore which took 30 hours to reduce without alkali could be perfectly reduced in 6 hours with it. Subsequent investigation showed that lime answered as well as any other alkali, and that an addition of 5 per cent. was amply sufficient. It was then found that the old form of furnace was not adapted to quick reduction, and the system of external heating was abandoned, and that of passing hot carbonic oxide through the mass of ore and carbonaceous matter was adopted. The following is a description of the furnace:

A vertical retort of fire-bricks, with an external wrought-iron casing, stands upon an entablature supported on columns. The retort is continued below the entablature by a wrought-iron cylinder with water-jacket; or, as proposed by Mr. J. Ireland of Manchester, England, instead of one wrought-iron cylinder four small ones are suspended, which split up the hot sponge into small columns, by this means effecting the cooling more rapidly. At the lower extremity of each cylinder is a conical mouthpiece and valve, by which the iron sponge can be discharged periodically into any receptacle placed beneath. The retort is filled by an ordinary bell and hopper. The carbonic oxide is generated in a gas-producer placed a few feet from the reducing furnace, and connected with it by a flue. The producer is circular in section, formed of wrought-iron plates, lined with fire-brick, and standing on an entablature supported by columns. Below the entablature is suspended a wrought-iron continuation, tapering to a conical discharging-valve for allowing the ashes to be from time to time

removed. Apertures for admitting air for combustion in the gas-producer are placed in its circumference, fitted with slide-covers to regulate its admission. The cost of producing iron sponge by this process in England was estimated by Mr. Ireland in 1878 to be 22*s*. per ton, exclusive of the ore. He states that iron sponge melts readily in a cupola furnace, and the risk of oxidation is less than when it is thrown into a bath of pig iron in an open-hearth furnace. To produce 100 tons of the metal per week, he estimates the cost of plant at about £2,500—two reducing furnaces, two cupolas, fan or blower, small engine and boiler, hoist, and ore-breaker, being all that is required. (*Journal of the Iron and Steel Institute*, i., 1878, p. 48; *Transactions of the American Institute of Mining Engineers*, vol. ii., p. 175.)

The inventor has furnished the writer of this with a few notes of the results of the later experiments made in Pittsburgh, as follows: The sponge was produced regularly, and in considerable quantities, as four furnaces, each containing three retorts each 3 ft. in diameter, were kept steadily in operation. Having at command such unprecedented quantities of iron in this rare form, opportunity was afforded for experimenting upon it on a large scale, and the following facts were developed:

1. Iron sponge cannot be economically cleaned of its earthy constituents by simply bringing it to a welding heat and hammering. If carried far enough to make clean iron, the loss is excessive.

2. It is not valuable as an adjunct to puddling, if introduced in lumps; if fine-ground, it greatly accelerates puddling, but the iron is not so clean.

3. It can be used in the open-hearth steel melting furnace if in pieces of half an inch diameter or over, simply thrown in cold, or roughly balled up in a scrapping furnace and cast in hot. The waste need not exceed 16 per cent., and the quality of product is the best that the ore is capable, under any process, of producing.

4. It can be readily run through a cupola and carbonized up to a point of fair fluidity, without imparting to it over one-half of 1 per cent. of silicon.

The general conclusions arrived at after the production and utilization of about 1,000 tons of iron sponge at Pittsburgh were:

1. That a state of fusion is necessary somewhere in the course of working, in order to give a desirable product.

2. That the open-hearth melting furnace affords an excellent means of treatment.

3. That the proper field for the process appears to be at the mines of rich iron ores, where, with simple apparatus, the sponge can be produced, run through a cupola, and its resulting metal sent into market as a cheap and valuable stock for further metallurgical operations.

Du Puy's Direct Process.—In 1853 Mr. Charles M. Du Puy of Philadelphia began a series of experiments on reducing iron ore by means of carbonaceous fuel in closed vessels. Experiments in this direction were made as early as 1791 by Lucas, who patented a process for reducing iron with carbon in air-tight pots, and by Mushet in 1794, who forged iron which he had carefully reduced away from the atmosphere, and brought to the pasty state in a crucible. In 1877 Mr. Du Puy patented his latest improved process, which is thus described: Rich hematites or magnetites are crushed and pulverized, together with charcoal or other fuel and fluxes in the proper proportions, in an ordinary "Chilian" mill, such as is used for grinding the "fix" for puddling furnaces. This mixture is then filled into annular sheet-iron canisters, of No. 26 iron, which are about 16 in. in diameter and from 16 to 38 in. high, the hole in the centre being 6 in. in diameter, holding enough ore to make a cake of metal that will shingle from 100 to 250 lbs. of iron. The fuel used for deoxidation may be either charcoal, coke-dust, or anthracite-dust. The canisters are placed on end in an ordinary reverberatory furnace, on a bed of coke, 7 or 8 in. apart, so as to allow a full circulation of heat. The heat is urged to a full welding temperature, and in about 5 or 6 hours the canisters with their contents have consolidated into masses of metal, saturated with pasty slag, which after being transferred to a hammer are made into blooms without reheating. Of the practical capacity of this process the inventor writes as follows: "Suppose a furnace is constructed 10 by 15 ft. inside capacity, to hold 5 rows of these canisters (38 in. high) one way, with 7 canisters the other, placed 8 in. apart and 8 in. from the furnace walls; then the furnace would hold 35 canisters, each containing about 400 lbs. of ore, of 67 per cent. metallic iron. They would be reduced in 6 to 7 hours, but say 3 charges were made in 24 hours. Each canister of 400 lbs. of ore yielding 80 per cent. or 230 lbs. of metallic iron hammered or squeezed, the furnace would produce 8,000 lbs. of iron at a charge, or 24,000 lbs. of muck-bar every 24 hours."

Several practical tests of the process, made in Pittsburgh and elsewhere during 1877-'78, have given most excellent results as regards the quality of the iron produced. An analysis of iron made by it from Republic (Lake Superior) ore gave 99.7 per cent. metallic iron, 0.042 carbon, 0.021 silicon, 0.032 sulphur, 0.016 phosphorus, 0.185 slag. The ore from which this iron was made contained 0.053 phosphorus. The purity of the iron makes it equal to the best brands of Swedish iron used for crucible steel or other purposes where great purity is essential. (*Journal of the Franklin Institute*, December, 1877, and December, 1878.)

Peckham's Direct Process.—This process, which appears to be an improvement on the Catalan process, is described in a report by Prof. H. S. Osborn (*Iron Age*, May 31, 1878). A few extracts from this report will give an idea of its method of operation: "The plan adopted by Mr. Peckham is one of three stories, or retorts, with flues on each side, provided with dampers so arranged that each crucible or retort may be kept at a uniform and at any desired heat. Each crucible or retort and flue is provided with a door in its rear or back end. This enables the careful manager not only to determine the degree of heat, but also if he chooses to examine the ore as to its progress in deoxidation. He can either continue the heat or draw the ore down to the next lower story or crucible, on its way to the inclined plane or floor, along which the ore is conveyed when deoxidized to the hearth or fire without exposure to the cold air." "Mr. Peckham's method, summarily, consists in heating the ore in the presence of carbon in air-tight crucibles, or retorts, at suc-

cessively increased but uniformly maintained temperatures, commencing at a very low heat. He then transfers the treated ore, or resulting metallic iron, while yet hot, and without exposure to cold air, to a forge fire, wherein it is worked. The ore is mixed in proper proportions with the charcoal let in upon the uppermost shelf or floor of a horizontal crucible; there it receives the first roasting, in connection with charcoal and carbonic oxide, from the fire of the hearth. It is then passed downward and let fall upon the next lower crucible floor, where it readily takes up more carbon, which combines with the remaining oxygen of the ore and passes off. It now begins to become metallic iron, and the heat, increasing at the next lower chamber or crucible, reduces the ore more fully to the metallic condition. Without exposure to the chilling contact with air, it is immediately drawn down upon the fire of the hearth and balled into the loop, and thence sent to the hammer to be made into blooms or billets."

Mr. Peckham states, November 27, 1878, that his process has been in use for over two years by Bowen & Signor of Saranac, N. Y., who are making some 2,000 tons of iron a year by it, which is used for horse-nails, fine rivets, etc., in place of Norway or Swedish iron. It is also in operation at Kimmswick, Mo., at the works of the Peckham Iron Company. Using Iron Mountain or other good ores, it requires, for 2,240 lbs. of blooms, 1¾ ton of ore and 160 bushels of charcoal. Each furnace will turn out about 3,600 lbs. of blooms in 24 hours.

Another modification of the Catalan process is now (1879) being experimented upon by the Horicon Iron Company at Ticonderoga, N. Y. In this, as in the Peckham process, the ore descends through a retort-chamber, where it is partially reduced before being drawn into the fire. Its chief peculiarity consists in the charging of the very fine ore-dust into another chamber, where it is preheated, and then taken by a screw conveyer and carried through a small gas-pipe into the tuyere, which conveys it into the forge fire and deposits it upon the surface of the loup. In this way, it is claimed, a loss of fine ore is avoided and a saving of fuel effected.

The Ellershausen Process.—Between the direct and the indirect processes for making wrought iron may be placed the Ellershausen process, since it is virtually a combination of both. In this process the purer varieties of ore are powdered and mixed with the molten pig iron as it flows from the blast-furnace. The oxygen of the ore partially burns out the carbon and the silicon of the pig, and the blooms formed consist of a conglomerate of partially decarbonized pig iron and granulated iron ore. These are subjected to a high heat in a puddling furnace, to reduce or separate the superfluous ore, and are then rolled into bars. The process was in operation for more than a year in Pittsburgh in 1868–'69, and for some time in Troy, N. Y.; and at one time it was thought to be a complete success. After a thorough trial, however, it was abandoned on account of its want of economy. (For a full description see Osborn's "Metallurgy," page 860 *et seq.*)

II. Indirect Processes.

These include all those processes in which wrought iron is made by decarbonizing pig iron. The process which is now most extensively employed for this purpose is that of puddling. But before the introduction of puddling the conversion was effected in a "finery" or hearth.

The Finery Processes.—These have undergone numerous modifications in different localities, but they are all substantially the same in principle. Professor Turner describes no less than fourteen distinct varieties, which are comprised in three general classes, viz.: the once-melting-down process (*Einmalschmelzerei*), the Walloon process (*Wallonschmiede*), and the German or breaking-up process (*Deutsche oder Aufbreckschmiede*). The first of these has six subdivisions, the others four each. Three only of the fourteen varieties are considered by Percy as worth describing—the Swedish, the English, and the Styrian Walloon processes. The English is subdivided into two varieties, the South Wales and the Lancashire processes. These we shall describe briefly.

In the South Wales process, the apparatus consists of a "melting finery," commonly termed a "refinery"* or "run-out," described more particularly hereafter, and two charcoal fineries or hearths. The pig iron is melted under coke in the melting finery, and the molten metal is allowed to flow into the two charcoal fineries supposed to be ready to receive it. Each of the latter is merely a shallow quadrangular hearth formed of iron plates, surmounted by a fire-brick stack. Cold blast is used, supplied through one tuyere. The molten metal as it flows into the finery partially solidifies, and is at once broken up by an iron bar. Charcoal is thrown in, with which the iron is mixed, and the mass heaped up on the side next the tuyere. Water is thrown at intervals over the charcoal to prevent its unnecessary waste. If this is not done frequently, great loss of fuel occurs. The metal is loosened and raised up and cinders tapped off from time to time, and the blast kept on constantly for about an hour. At the end of this time the metal is thoroughly decarbonized, becomes pasty, and is welded together into a ball, which is taken out and hammered into any desired shape.

The finery known as the Lancashire hearth is still used extensively in Sweden. As in the South Wales process, the furnace consists of a cavity formed of cast-iron plates. The plate at the bottom is kept cool by flowing water. The side walls above the hearth are protected by cast-iron plates. Hot blast is used through one water-tuyere with semicircular-shaped nozzle. The axis of the tuyere is inclined at an angle of about 10°. The apparatus for heating the blast is merely a siphon pipe of cast iron placed in a chamber above the hearth. A cast-iron plate is provided upon which pigs or blooms may be heated, thus economizing the heat of the waste gases. In the operation of this hearth, it is filled with clean charcoal, and then a charge of 200 lbs. of pig iron in plates 2 in. or 3 in. thick, which has been previously heated on the cast-iron plate, is transferred to the hearth. Fresh charcoal is added and the blast turned on, when in about half an hour the metal will have completely melted down, and in dropping through the blast from the tuyere will have become partially oxidized.

* The terms finery and refinery are sometimes used indiscriminately. The nomenclature used by Percy is followed here, making refinery mean the furnace in which partial decarbonization is effected (the "run-out"), and finery the furnace in which the decarbonization is completed.

After complete fusion the fining proper begins. This consists in continually breaking up the metal with a bar, and carrying toward the tuyere the raw or insufficiently decarbonized portions, which being more fusible than the rest run to the bottom and there harden. This operation lasts about half an hour. Subsequently all the metal is brought up to the top of the hearth and again melted down at a high heat to form the ball, fresh charcoal being thrown in at intervals. The ball is then taken out and hammered. The bloom thus obtained, when the workmen are skilled, is very sound and free from impurities. The following commercial details of the Lancashire process, as carried on in Sweden, are given by Percy:

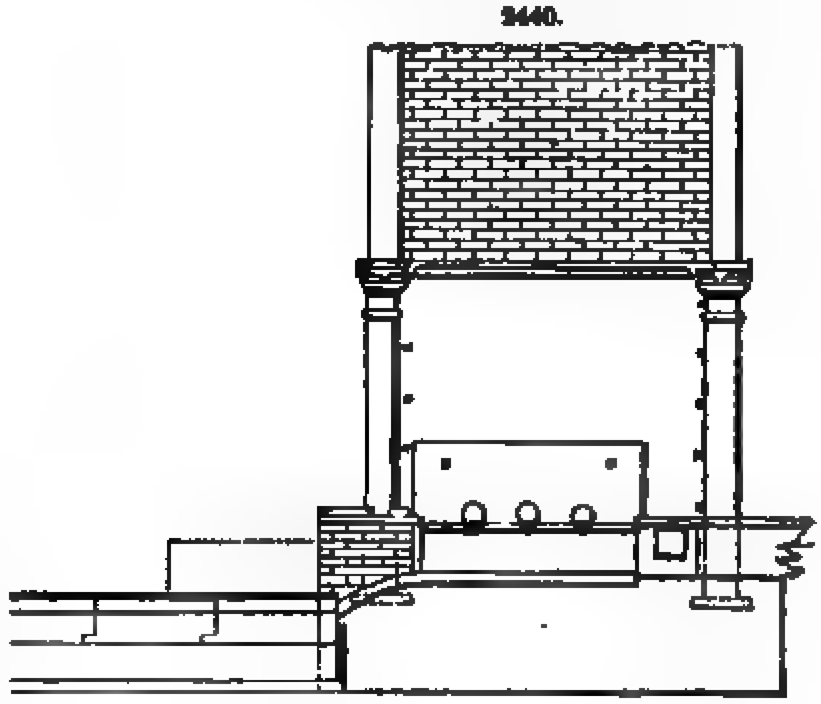
Average weight of blooms from one finery per week, tons	6.6
Weight of bloom per cent. of pig iron	86.75
Charcoal consumed per ton of blooms, by weight, tons	0.9
" " " " by volume, cubic feet	255

In the United States the finery processes are still carried on to some extent. The works are known as bloomaries or forges, which names, as before mentioned, are also indiscriminately applied to Catalan forges. The furnaces are known as fineries or knobbling fires. In 1878 there were reported 56 works with an annual capacity of 65,000 net tons, of which 36 works with a capacity of 40,000 tons are in Pennsylvania, chiefly in the central portion of the State. Fineries in Pennsylvania usually work 12 hours a day, and make in that time six loops weighing about half a ton; the product of a fire is therefore about three tons per week. Instead of pig iron, refined or plate metal from the run-out or refinery is sometimes used, requiring a smaller amount of fuel and a shorter time to complete the operation than when pig iron is used. With refined metal a fire may make a ton per day. A ton of billets requires usually about nine-tenths of a ton of charcoal and 24 cwt. of pig iron.

In November, 1878, there were seven varieties of blooms or billets quoted in the Philadelphia market, some made by the Catalan direct process, others by the bloomary indirect process. The following will give an idea of the names of these blooms, their relative value, and the purposes for which they are chiefly used: 1. Champlain ore blooms, $38 to $39 per ton of 2,240 lbs. Made in the Catalan forge, principally in the Champlain district in New York, but a few in New Jersey and the South. Used for C. No. 1 plate iron, and for sheared "skelp" for tubes, but now in little demand. 2. Charcoal-scrap blooms, $37 to $39 per ton of 2,240 lbs. at forge. Made in all sections of the United States by "sinking" scrap with charcoal in a bloomary or reverberatory furnace. Used for C. H. No. 1 boiler-plate, and for wire purposes. 3. Best charcoal blooms, $53 to $55 per ton of 2,240 lbs. Same as No. 1, but made from high-grade magnetic ores containing but little phosphorus. Used for crucible steel. 4. Best charcoal bars, $60 to $65 per ton of 2,240 lbs. Made from No. 3 by hammering or rolling. Bars 12 ft. long by 3½ by ⅝ in. Used principally in Pittsburgh by crucible-steel makers. 5. Cornered blooms, $60 to $65 per ton of 2,464 lbs. Made in bloomary fires with charcoal from pig iron (chiefly from charcoal pig), principally in Pennsylvania. They are small blooms, 24 in. long by 4½ to 5 in. square, with beveled edges; hence the name cornered. Used for thin sheets. 6. Cold-blast charcoal blooms, $57 to $60 per ton of 2,240 lbs. Made in bloomary fire with charcoal from cold-blast charcoal pig. Localities, Cumberland, Susquehanna, Schuylkill, and Juniata valleys, Pennsylvania. Used for best flange boiler-plate. 7. Anthracite pig blooms, $50 to $51 per ton of 2,240 lbs. Made from anthracite pig in bloomary fire. Fuel generally charcoal, although coke is sometimes used. Made throughout Pennsylvania. Used for flange boiler-plate, the writer's informant says, "if the conscience of the user will permit." They are not as reliable in quality as No. 6. At the time the above quotations were given, forge pig was

2439.

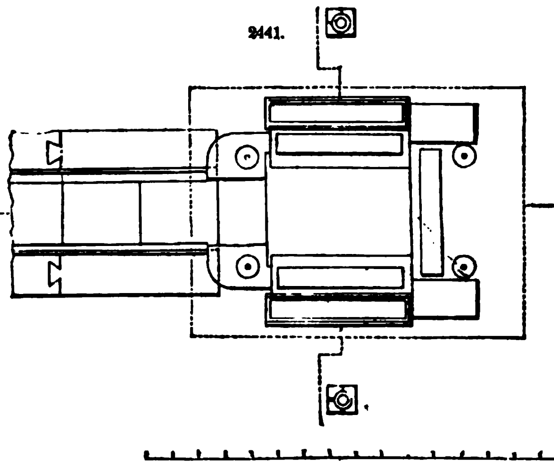
2440.



quoted in Philadelphia at $15.50 to $16.50, and ordinary wrought-iron bars (made in the puddling furnace) at from $35.80 to $42.66 per ton of 2,240 lbs. The high prices obtained for the charcoal blooms are evidence of their superior quality.

The Refinery or Run-out Fire.—This may be considered as an auxiliary to either the finery or the puddling furnace. Its object is the partial purification of the pig iron preparatory to its more complete purification in other furnaces. It is now but little used in the United States, but is still used to some extent in Europe. The refinery is illustrated in Figs. 2439, 2440, and 2441, taken from Percy's "Metallurgy." It consists essentially of a rectangular hearth with two or more (often three) water-tuyeres on each side, inclining downward. The sides and back are formed of hollow iron castings called water-blocks, through which water is kept flowing, the front of a solid cast-iron plate containing a tap-hole, and the bottom of sand resting on a solid platform of brickwork. Coke is used as fuel, with cold blast at a pressure of about 3 lbs. per square inch. The space immediately over the hearth is inclosed on each of the two sides either by a brick wall or by a cast-iron plate; the front and back with folding wrought-iron doors, which are frequently left open. Above this space is a short chimney supported on cast-iron columns.

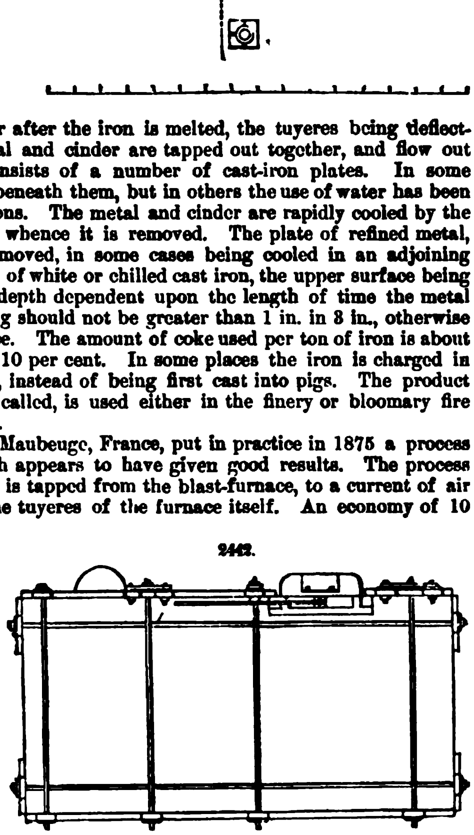
2441.



In the operation of the refinery a charge of coke is thrown upon the hearth, and upon it about 1 to 2 tons of pig iron, with a small portion of hammer-scale. The blast is turned on and the metal melted, running through the coke to the bottom of the hearth. The blast being strongly oxidizing, a considerable quantity of cinder is formed, and the iron is deprived of most of its silicon and a portion of its carbon. The blowing lasts for about half an hour after the iron is melted, the tuyeres being deflected upon the surface of the iron, when the metal and cinder are tapped out together, and flow out along the running-out bed in front, which consists of a number of cast-iron plates. In some places these plates are cooled by flowing water beneath them, but in others the use of water has been abandoned on account of the danger of explosions. The metal and cinder are rapidly cooled by the cast-iron plates, and the cinder rises to the top, whence it is removed. The plate of refined metal, about 2 or 3 in. thick, is then broken up and removed, in some cases being cooled in an adjoining trough filled with water. It has the appearance of white or chilled cast iron, the upper surface being of a cellular structure or "honeycombed" to a depth dependent upon the length of time the metal has been blown. The depth of the honeycombing should not be greater than 1 in. in 3 in., otherwise the metal is hard to melt in the puddling furnace. The amount of coke used per ton of iron is about 4 cwt. The loss in weight of the iron is about 10 per cent. In some places the iron is charged in the melted state directly from the blast-furnace, instead of being first cast into pigs. The product of the refinery, plate-metal, as it is commonly called, is used either in the finery or bloomary fire heretofore described, or in the puddling furnace.

Hamoir's Process.—M. Ferdinand Hamoir, of Maubeuge, France, put in practice in 1875 a process for refining cast iron previous to puddling, which appears to have given good results. The process consists in submitting cast iron, at the instant it is tapped from the blast-furnace, to a current of air from the same blast that is being supplied to the tuyeres of the furnace itself. An economy of 10 per cent. of the coal required in puddling is said to be the direct consequence of the partial decarbonization thus effected, and in 24 hours, with the same quantity of coal, two charges more per day are obtained from the puddling furnace. (*Journal of the Iron and Steel Institute*, ii., 1875, p. 660; i., 1876, p. 184.) W. K.

2442.

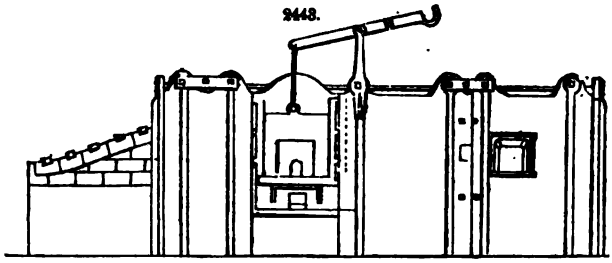


IRON-MAKING PROCESSES—PUDDLING. The puddling process consists essentially in stirring about molten pig iron on the bed of a reverberatory furnace, heated by the flame produced by the combustion of fuel in an adjoining chamber, until the silicon, carbon, sulphur, phosphorus, and other impurities of the iron are oxidized and removed, and the iron thereby rendered pasty when heated and malleable when cold. The process was patented by Henry Cort in England in 1784. Fairbairn states that Cort "expended a fortune of upward of £20,000 in perfecting his inventions for puddling iron and rolling it into bars and plates; that he was robbed of the fruit of his discoveries by the villainy of officials

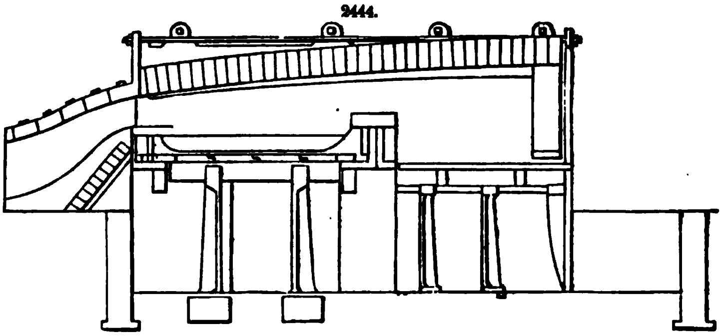
in a high department of the Government; and that he was ultimately left to starve by the apathy and selfishness of an ungrateful country." He states further that Cort's inventions "have conferred an amount of wealth on the country equivalent to £600,000,000 sterling, and have given employment to 600,000 of the working population of our land for the last three or four generations."

The puddling-furnace is represented in the accompanying engravings. Fig. 2442 is a top view, Fig. 2443 a side elevation, Fig. 2444 a longitudinal section, Fig. 2445 a horizontal section, and Fig. 2446 an elevation at the fire-place end of the furnace. The furnace consists externally of an oblong casing of iron plates, firmly bound together by iron tie-bars, and lined with fire-brick. The fire-grate is separated from the working-chamber of the furnace by a wall known as the bridge-wall, over which the heated products of combustion pass and play upon the surface of the molten metal and effect its conversion, and pass thence through the "neck" to a chimney, usually 30 or 40 ft. high, which is closed by a damper. Either blast or natural draught may be applied to effect the combustion of the coal in the fire-box. In some cases a steam-boiler is supported on pillars above the puddling furnace, and the products of combustion are caused to pass in a flue beneath it, or through its internal flues, before entering the chimney, thus utilizing a portion of their waste heat. The working-chamber is dish-shaped, and is constructed of cast-iron plates, the sides being usually hollow blocks through which a stream of water or of air is allowed to pass to cool them and prevent their burning

2443.



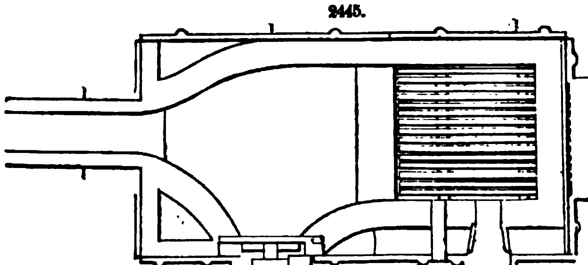
2444.



out. Free access of air is also allowed beneath the bottom plate for the same reason. The sliding door shown is lined with fire-brick.

Fig. 2447 represents a longitudinal section of an improved form of puddling furnace, known as Caddick and Mayberry's furnace. It consists of a chamber or gas-generator of fire-bricks, surrounded by a casing of thin iron plates, say three-sixteenths of an inch thick, and a puddling hearth. The whole of the plates are of wrought iron, the buckstaves or binders being cast-iron columns, held together at the top by suitable tie-rods. The ordinary sliding fire-brick door is used, but outside of

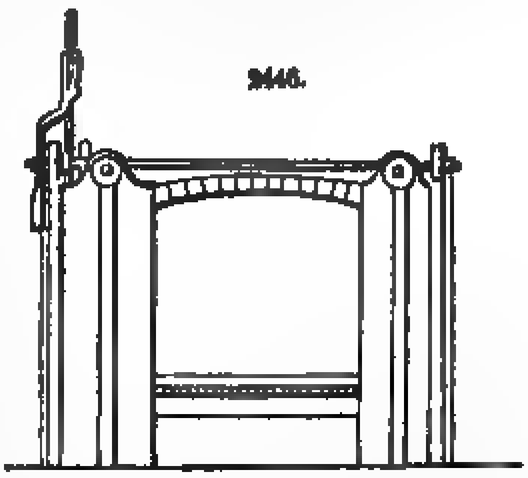
2445.



this is provided a second door of thin plate iron, in which a suitable aperture is made to admit the rabble; this door acts in protecting the puddler from radiant heat. *A* is the generator, *B* the inner casing, and *C* the outer casing. Blast is admitted into the space between the inner and the outer casing through the pipe *D*; the air becomes heated by coming into contact with the inner casing, and passes into the inclosed space below the grate-bars, through holes formed in the lower part of this casing. Here the already heated blast is heated to a further degree by the red-hot ashes. A

portion passes up through the grate-bars, while another portion is admitted to the combustion-chamber above the level of the fire. The result is complete combustion, so that smoke is practically prevented, and saving of fuel is effected. The admission of the blast over the fire is regulated by a valve *F*. The frame which contains this valve is provided with a slide having sight-holes, through which the holes in the brickwork may be kept free from obstruction. Blast is supplied by a fan.

2446.



In the operation of puddling, the furnace being heated to a high temperature, a charge of 400 to 500 lbs. of pig or plate metal is introduced into the working-chamber, and in about half an hour it is all melted. The "puddler" and his "helper" then alternately stir about the iron, or rabble it as it is called, in such a manner as to expose thoroughly every portion of the iron to the action of the flame, which is strongly oxidizing in consequence of its containing an excess of air from the atmosphere. The door of the furnace is closely shut, except the small hole, which is just large enough to admit the rabble of the puddler, and allow him to see into every part of the working-chamber. The whole operation requires usually from 1½ to 2 hours. Cort's patent in describing the process says: "After the metal has been some time in a dissolved state, an ebullition, effervescence, or such-like intestine motion takes place, during which a bluish flame or vapor is emitted; and during the remainder of the process the operation is continued (as occasion may require) of raking, separating, stirring, and spreading the whole about in the furnace, till it loses its fusibility, and is flourished or brought to nature. As soon as the iron is sufficiently in nature, it is to be collected together in lumps called loops, of sizes suited to the intended uses, and so drawn out of the door or doors of the furnace."

The bed of the puddling furnace introduced by Cort was of sand, and continued to be so made until about the year 1818, when Mr. Samuel Baldwyn Rogers of Glamorganshire substituted the

2447.

weekly yield of a furnace to 20 or 24 tons." Cort speaks of his furnace as being charged with "sow and pig metal," but it was generally customary, prior to the introduction of the improvement known as boiling, to use plate metal from the run out fire, in which the purification of cast iron is partially effected. By the use of plate metal the time necessary for the operation is greatly diminished, as is also the waste of metal.

The Boiling Process.—Shortly after the invention of the iron bottom for puddling furnaces, a modification was introduced in the process, which consisted chiefly in the addition of hematite or specular ore with hammer- or roll-scale to the charge of pig iron. These are called the "fettling" or "fix." The ore and scale, being on the bottom of the hearth under the charge of melted pig iron, give up their oxygen, which unites with the carbon and silicon of the pig iron, hastening its purification. The ores at the same time become deoxidized and reduced, forming metallic iron, which unites with the malleable iron converted from the pig, and thus increases the yield. Mr. S. B. Rogers, in his "Metallurgy," says: "There are two processes made use of, bearing distinctive names, which properly come under the denomination of puddling: first, puddling as originally invented by Mr. Henry Cort, and second, boiling, a working of cast iron in a bath of fluid iron cinders, which has been practised for untold ages; there was no invention in the case, but only a modification," etc. Fairbairn, however, says Mr. Hall, of Bloomfield Iron Works, Tipton, may safely be considered as the first who introduced the system of boiling, which ultimately dispensed with the refinery and established the more expeditious process of puddling direct from the pig. The process of boiling, or

"wet puddling," as it is sometimes called, has now almost entirely superseded the older form or "dry puddling"; but the latter is still used in some localities. In boiling, the "ebullition" or "effervescence" mentioned by Cort is much more energetic than in dry puddling. It is not a real boiling, however, but merely an intensely rapid generation of carbonic oxide within the body of the molten metal, by the union of the oxygen of the ore and scale on the bottom of the furnace with the carbon of the pig iron lying above. The effervescence causes the cinder to rise up over the bed of molten metal, and a portion of it runs out at the rabbling-hole, even though the latter is several inches higher in the boiling than in the old puddling furnaces. In the United States boiling is almost exclusively practised, the word puddling being still retained as the name of the process. Some details of the process, as conducted at a works in Pittsburgh, are as follows:

Each furnace is allowed 1,000 lbs. of specular ore in a double turn of 10 heats. The charge of pig iron to each heat is 475 lbs., and the yield in puddle-bar, weighed after being rolled, is about 480 lbs. There is thus a slight gain in weight over the iron charged, due to the iron reduced from the ore. When working single turn, each furnace makes 6 heats per day, the first furnace being charged at 3:30 A. M., and the last charge withdrawn at 1 P. M. Working double turn, 10 heats are made, the working time being from 3:30 A. M. to 7:30 P. M. Triple turn has been practised to some extent, 15 heats being made in 23 hours, or from 2 A. M. to 1 A. M. the next day. The capacity of each furnace per day therefore is: single turn, 2,880 lbs.; double turn, 4,800 lbs.; triple turn, 7,200 lbs. The consumption of fuel in puddling (or boiling) varies, according to the quality of the coal and of the iron, the skill of the workman, and the length of time in the 24 hours that the furnace is in operation, from 1,600 to 3,000 lbs. per ton of 2,240 lbs. of product. It is found that by working double turn there is usually a saving of 20 per cent. of fuel over working single turn, and that a double furnace (one in which there are two working-doors, and in which a double charge is worked) there is a saving of 10 to 20 per cent. over the single furnace.

There are three great objections to the puddling process, as described above, which inventors have long labored to remove. These are: the large amount of severe labor required, two skilled workmen being needed at each furnace; the variable quality of the product, dependent upon the skill and trustworthiness of the workmen; and the great consumption of fuel. In the modern types of puddling furnace in which economy of fuel is attempted, the waste heat is usually applied to heat the air required for the combustion of the fuel, or to heat the gaseous fuel itself, or both. In furnaces designed to economize labor, the iron is either stirred by rabbles worked by machinery, or the working-chamber is caused to rotate or oscillate, the motion of the furnace being substituted for the motion of the rabbling tools. Uniformity of product is secured by perfect uniformity of working, and by properly controlling all the operations. In many recently invented furnaces the appliances for economizing fuel and labor are combined. The improved furnaces have reached their greatest development in England, where they are replacing the old furnaces so rapidly as to lead to the belief that the latter will soon be entirely disused. On the continent of Europe and in the United States the introduction of the improved furnaces has been slower, but none the less sure. Chief among the improvements designed to effect economy of fuel is the Siemens regenerative furnace, which is applicable to almost (if not quite) every department of metallurgy in which intense heat is required. In the manufacture of iron it is especially used for heating iron and melting steel. For these purposes it has been one of the most valuable inventions of this century. In puddling, its use has been until recently comparatively restricted, but it is now increasing. A brief description will here be given.

The Siemens Regenerative Furnace.—The regenerative gas system, invented by Dr. C. W. Siemens in 1862, may be generally described as a producer, in which gas is generated from coal, wood, peat, or other fuel, and a chamber termed a regenerator, divided into four compartments, filled with loosely stacked fire-bricks, which are placed immediately under the furnace. The gas-producers may be erected at any practicable distance from the furnace to which they are to be applied. The producer shown in Fig. 2448 is a rectangular fire-brick chamber, one side of which is inclined at an angle of 45° to 60°, and is provided with a grate at its foot. The fuel is filled in at the top of the incline, and falls in a thick bed upon the grate. Air is admitted at the grate, and as it rises slowly through the ignited mass it generates the gaseous fuel which is burned in the furnace. The composition of the gas varies with the nature of the fuel used and with the management of the gas-producer. One analysis, of gas made by burning a mixture of three-fourths caking and one-fourth non-caking coal, is as follows:

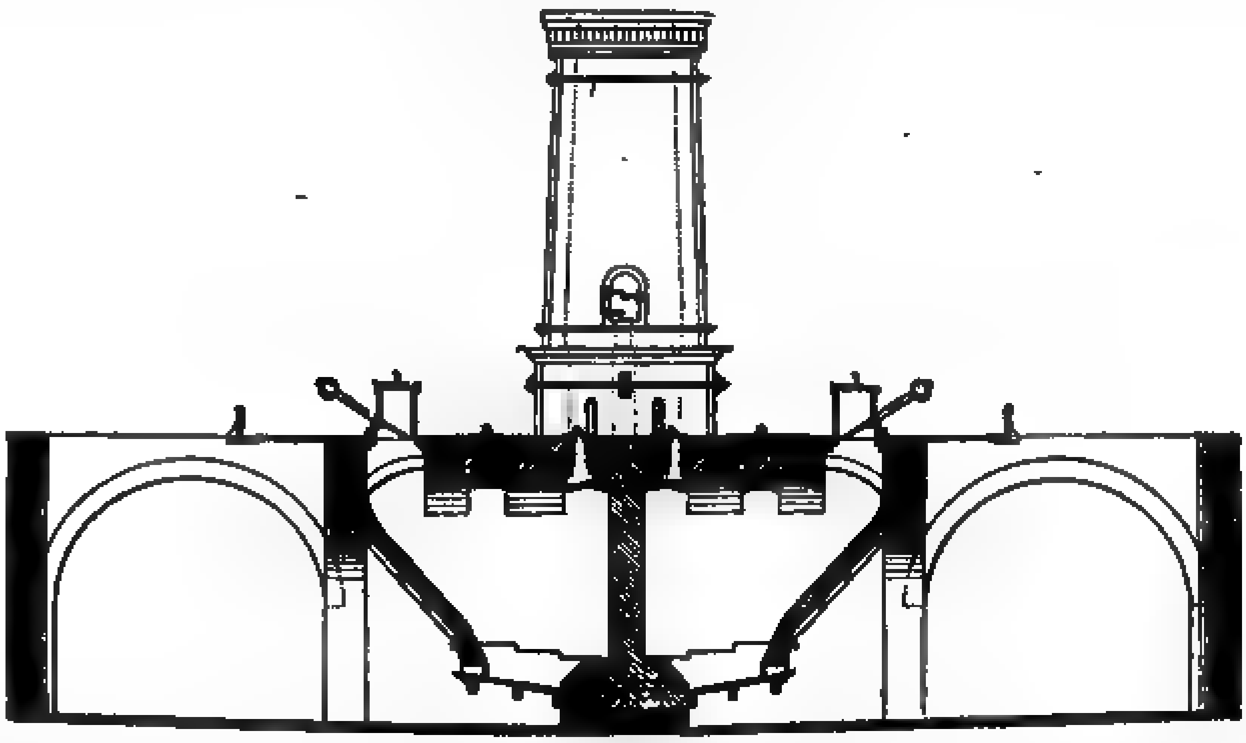
Carbonic oxide	24.2	volumes.
Hydrogen	8.2	"
Carburetted hydrogen	2.2	"
Carbonic acid	4.2	"
Nitrogen	61.2	"
	100.0	

The gas leaves the fuel at a temperature of about 1,000° F., and ascends into the upper part of the producer with a slight outward pressure. It is usually carried upward to a height of 8 or 10 feet above the producer, and is then led along through a horizontal sheet-iron tube, from which it passes down to the regenerative furnace, either directly or through an underground flue.

In the regenerative chambers the gas and the air employed for its combustion are separately heated by the waste heat of the flame from the furnace above. These are four chambers, filled with fire-bricks, stacked loosely together so as to expose as much surface as possible. The waste gases from the flame in the working-chamber of the puddling, heating, or other furnace to which the regenerators are applied, are drawn down through two of the regenerators, and, heating the upper

rows of bricks to a temperature little short of that in the furnace itself, pass successively over cooler and cooler surfaces, and escape at length to the chimney-flue nearly cold. After heating these two chambers for a certain length of time, the direction of the draught is reversed. The current of flame or hot waste gases is then employed to heat up the second pair of regenerators, and the gas and air entering the furnace are passed in the opposite direction through the first pair, and, coming into

2448.



contact with the brickwork, are heated as they ascend, until at the top they attain a temperature nearly equal to the initial heat of the waste gases. Passing up into the furnace, the gas and air meet, and, thus heated, they at once ignite, producing an intensely hot flame. The flame after traversing the working-chamber is drawn down through the second pair of regenerators to the chimney-flue. The current is continued in this direction until the uppermost courses of brickwork in the first pair of regenerators begin sensibly to cool; but by this time the second pair are sufficiently heated, and the draught is again reversed. By reversing the draught at regular intervals, nearly all the heat is retained in the furnace which would otherwise escape, the temperature in the chimney-flue rarely

2449.

exceeding 300° F., whatever may be the heat of the furnace. In addition to the economy in the amount of fuel used, a much cheaper quality (such as coal-slack) may be generally burned in the gas-producer than could be used in a furnace working at the same heat, and in which the fuel is burned directly upon the grate in the ordinary way.

Fig. 2449 represents a Siemens regenerative furnace for heating iron. For puddling, the only essen

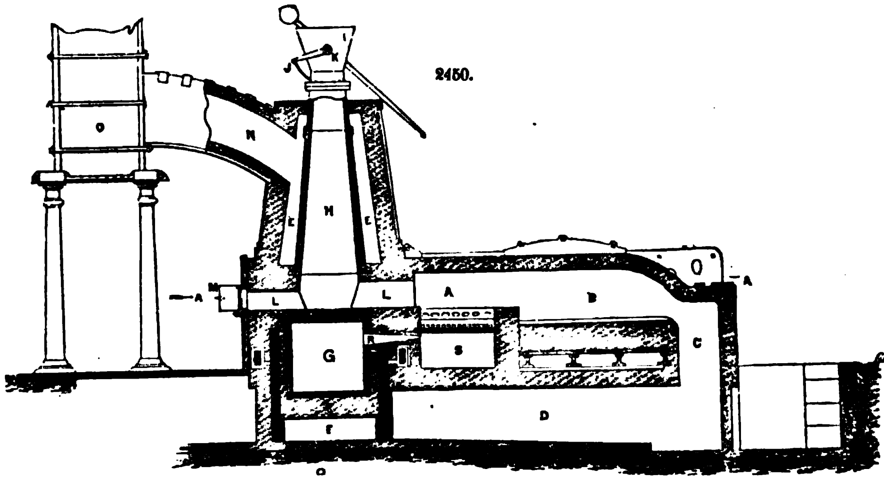
tial difference is in the shape of the working-chamber. The gases from the producer entering at *R R* on the right, and the air for their combustion entering at *O O*, pass upward through the heated regenerators *L L* and through the flues *M N* to the working-chamber *K K*, where they meet and ignite. The flame, after doing its work of heating the iron in *K K*, then passes downward as shown by the arrows through *M' N'* and the regenerators *L L* on the left, heating these as they pass through, thence through the reversing valve *S* to the chimney-flue *T*.

In puddling with the Siemens regenerative furnace, it is claimed that the heat can be raised to an almost unlimited degree, and that the flame can be made oxidizing or reducing at will, by varying the proportion of air and gas, without interfering with the temperature. The saving of fuel is claimed to be nearly 50 per cent. over the ordinary type of puddling furnace. The yield, as shown by a return of 80 consecutive charges of a single puddling furnace, was as follows: pig iron charged, average per heat, 483.3 lbs.; red ore for fettling, 92.6 lbs.; puddle-bar returned, 485 lbs. The gas-furnace turned out 18 heats in 24 hours, against 12 heats in 24 hours in the ordinary furnace. A rolling-mill supplied with 8 double puddling furnaces, each heated by the Siemens regenerative system, is now (1879) being built at McKeesport, Pa. It is expected that the capacity of these 8 furnaces will be 50 tons per day.

The Continuous Regenerator.—Several forms of so-called regenerative gas-furnaces have been devised, in which the currents of waste gas, fuel-gas, and air, instead of being reversed and passed through different chambers, are caused each to flow continuously through its own chamber. Usually the waste gas is applied to heat the air only, the gaseous fuel being taken directly from the producer, which immediately adjoins the regenerator, the waste gas and air passing in contrary directions through flues which adjoin each other. Such is the arrangement of the continuous regenerator of Messrs. William and George H. Sellers of Philadelphia. The products of combustion are caused to pass through a number of fire-clay tubes in a chamber underneath the furnace, and the air is heated by passing around these tubes. In this system a part of the heat of escaping gases is sometimes applied to heat the entering gas by means of a similar regenerator or tube-chamber.

In the continuous regenerator of Mr William Swindell of Pittsburgh, the products of combustion pass down under the puddling chamber through a series of flues which alternate with a series of air-flues, in passing through which the air is heated, which in the puddling or heating chamber burns the gas from the producer immediately adjoining the furnace. A number of flues are built above the puddling-chamber also, into which the air passes after passing through the flues beneath.

Price's Retort Furnace.—Mr. John Price of Sunderland, England, about 1875 introduced a furnace known as the retort furnace, which has met with considerable success as a puddling furnace in England. (*Journal of the Iron and Steel Institute*, ii., 1875, p. 453.) It has many of the merits of the regenerative furnaces, and is not so expensive in first cost. Fig. 2450 represents a longitudinal section of the furnace as adapted for heating. To make it a puddling furnace requires merely an alteration in the shape of the working-chamber. *A* is a combustion-chamber supplied with grate-bars; *B* a heating-chamber, separated from *A* by the usual bridge; *C* is the neck, descending into



2450.

an underground flue *D*, leading into an upcast or retort chamber, as it is designated, *E*. In the centre of the chamber *E* is a fire-brick circular pillar *F*, with spaces around, marked *E E*, and on which is placed a cast-iron cylindrical air-vessel *G*, which is protected by fire-brick. On this air-vessel *G* is built a retort *H*, partly of fire-brick, partly of cast-iron. The top of the cast-iron part of the retort is fitted with a hopper *I*, in the throat of which is a damper *J*, worked by a rocking shaft and lever *K* from the ground. The lower portion of the retort made of fire-brick has two necks *L L*, the one leading to the combustion-chamber for the passage of fuel, the other to the outside of the furnace for the insertion of stoking tools, to force the fuel forward into the combustion-chamber. The entrance of the outer neck is closed by an air-tight door *M*. The upcast or retort chamber *E* extends to near the top of the retort, where it is closed by brickwork, but is opened at the side by the flue *N*, leading to the stack *O*. Near the bottom of the chamber *E* are pipes *P*

passing around the chamber, and opening into the chamber *E* are a number of port-holes *Q*, leading to the space around the pipes *P* in which the latter are heated. The blast, entering through the pipes *P*, passes into the heated air-chamber *E*, thence through the outlet *R* into the ash-pit *S*.

In practice, a fire is lighted on the grate-bars, and the furnace well heated. The retort is then filled with fuel, and the firing commences from the retort; and by the time the fuel at the top descends to the bottom of the retort it is well heated, and a continuous supply of heated fuel is then kept up. The gases generated in the combustion-chamber *A* pass over the bridge into the heating chamber *B*, down the neck *C*, into the underground flue *D*, into the upcast or retort-chamber *E*, giving up their heat to the circular air-chamber *G*, the retort *H*, and the air-pipes *P*, their residue passing off by the flue *N* into the stack *O*. Combustion is supported by air under pressure from a fan. A return of a single-bedded puddling furnace working 12¼ tons of pig iron per week, and of a double-bedded puddling furnace working 25 tons per week, gave the following figures: The product of the single furnace during the time of the test was 212 tons of puddle-bars and scrap iron; of the double furnace, 653 tons. The consumption per ton of puddled iron and scrap was:

	Single Furnace.	Double Furnace.
Pig and scrap iron	20.70 cwt.	20.97 cwt.
Fettling	.46 "	.21 "
Coal	14.02 "	10.71 "

Bicheroux's Gas-Furnace.—This furnace, as successfully used for puddling at the Ougrée Iron Works, near Liége, Belgium, is thus described: The apparatus consists of three distinct parts: (*a*), a gas-producer, in which only a small quantity of air is admitted through the grate for the production of carbonic oxide; (*b*), a mixing chamber, in which this gas and air is collected by the natural draught, and in which the combustion of the gas begins; (*c*), a furnace or laboratory, in which the combustion is nearly completed, and where the different reactions in the puddling take place. The dimensions of each of these three parts vary with the composition of the different coals. Before the air arrives at the intermediate chamber, it is circulated beneath the bottom of the furnace, and in the sides of the chamber itself, in such a way that both the air is heated and the parts of the furnace are cooled which cannot be exposed to intense heat without injury. The usual dimensions of the puddling chamber are increased, and two working-doors are placed at opposite sides. The charge of pig iron at each heat is 400 kil. (8 cwt.). In regard to the economy of fuel of this furnace, it is stated that the puddling of ordinary white Ougrée iron, which required with an ordinary furnace 900 to 1,000 kil. (18 to 20 cwt.), is now done with less than 600 kil. (12 cwt.) per ton of puddled bars produced. The puddling of fine-grained iron, which required 1,300 to 1,500 kil. (26 to 30 cwt.), is now done with 800 kil. (16 cwt.). The economy in waste amounts to 3 or 4 per cent. The cost of repairs, wear and tear, and labor are also stated to be less than in the ordinary type of furnace. (*Revue Universelle des Mines*, 1877; *Journal of the Iron and Steel Institute*, i., 1877, p. 223.)

Several other gas-puddling furnaces have been introduced in various localities, the chief features of which consist in generating gas from coal or other fuel in a chamber, which may either immediately adjoin the puddling furnace or be removed some distance from it, and in burning the gas in the puddling chamber by means of a current of heated air. The air is heated either by passing through fire-brick flues over, under, or around the furnace, or through cast-iron pipes contained in a chamber annexed to the furnace. A combination of these plans is adopted in the furnace of Mr. William A. Sweet of Syracuse, N. Y.

Other modifications in the original forms of puddling furnace are the preheating or the melting of the iron in a separate chamber, the running it in a molten state from the blast-furnace or from a cupola into the puddling chamber, and the enlargement of the puddling chamber and placing two working-doors, one on each side of it, making what is called a double furnace. The furnace of Mr. Benjamin Bayliss of Pittsburgh has three distinct chambers: first, the melting chamber, from which the iron is tapped into the second or the refining chamber, where the iron is blown by a blast and partially purified as in the "run-out"; and third, the puddling chamber proper, in which the puddling operation is completed.

Hot air and steam have been combined to produce the gas from coal for puddling. The steam is superheated and introduced with the air below the grate, decomposing the coal and forming a gas which is burned by a blast of heated air in the puddling chamber. Natural gas has been used for about three years at the mill of Messrs. Spang, Chalfant & Co. at Sharpsburg, near Pittsburgh, the gas being brought from a well 17 miles distant through a 6-inch pipe. The results have been entirely successful both as to quality of product and economy of production. (Paper by Mr. John V. Pearse in Vol. L., "Second Geological Survey of Pennsylvania," 1875.) Dr. C. J. Eames of New York has successfully applied petroleum gas, made from crude petroleum and superheated steam, to the puddling and heating of iron; but his process has not yet been introduced on a commercial scale. (*Engineering and Mining Journal*, August 7 and 20, 1875.)

Mechanical Puddling Furnaces.—We come now to consider a few of the more prominent forms of mechanical puddling furnaces, in which the severe manual labor of the puddler is superseded by machinery. These may generally be divided into two classes: the first, those in which the puddling chamber itself rotates, and by its motion continually presents fresh surfaces of the molten metal to the gaseous current, thus producing the same effect as the stirring done by the puddler; the second, those in which the puddling chamber is stationary, and the rabbles are moved by machinery instead of by the hand of the puddler.

Danks's Rotary Puddling Furnace.—This furnace, the invention of Mr. Samuel Danks of Cincinnati, after many years of experimenting and the expenditure of large sums of money, has been made a practical success, and at the time of publication of this volume is in regular operation at the works of

Messrs. Graff, Bennett & Co., Pittsburgh; Messrs. Hopkins, Gilkes & Co., Middlesborough, England; and Messrs. Schneider & Co., Creusot, France. The furnace consists of a fireplace, a revolving cylindrical working-chamber, and a movable head-piece, and is represented in longitudinal section in Fig. 2451. The revolving chamber is 5 to 6 ft. in diameter and 3 to 4 ft. long. It rests on carrying-rollers which permit free rotation, and is made to revolve by means of a special engine geared to it by toothed wheels. The cylinder is open at both ends: one end butts against a ring that is fastened to the bridge-plate in the stationary fire-box; the other against the movable head-piece, which serves both as doorway and as flue connecting with the chimney. The bridge-plate and its ring and the joints at the head-piece are cooled by water. The stave-plates forming the cylinder have hollow ribs to hold the lining. The ash-pit and fire-hole have closed doors, and the air is fed to the furnace by means of a fan-blast. The chamber is lined with a thick paste of pulverized ore and pure lime. The fettling is then made by throwing in pulverized ore and melting it, thus glazing the lining. In the operation of the furnace, after the pig iron is melted (either in the furnace itself or in a cupola or other auxiliary melting furnace, from which it is transferred), the working-chamber is rotated about 6 or 8 turns per minute. In about 20 minutes the iron begins to granulate, or "come to nature," and in about 7 minutes more it balls together in a pasty mass, which rolls and turns from side to centre as the rotation continues, accumulating largely at every turn of the furnace. The puddler now takes a light tool, pushes straggling pieces of the pasty mass into the main body, and then stops the furnace to arrange the iron ready for balling. The mass is next thoroughly heated for about three minutes; then, slowly rotating the furnace, the puddler by the aid of his tools folds the mass over itself, and it is rolled together in a spongy porous ball. The movable head-piece being pushed to one side, the ball is then removed from the furnace by means of a large fork suspended from a crane, and carried to the squeezer.

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The following commercial details of working of the Danks furnace for two months in 1877 are given in a paper by Mr. John I. Williams, superintendent of the Millvale Works of Messrs. Graff, Bennett & Co., to whom is due the credit of having first made the Danks furnace a practical success. In these furnaces the iron is melted in the revolving chamber.

Actual number of days worked	37
Number of heats made with nine furnaces, single turn	1,941
Amount of metal charged, lbs.	1,746,900
Amount of muck-bar and croppings, lbs.	1,693,010
Total loss, lbs.	53,890
Percentage of loss	3.080

The amount of coal used for the above, including lighting, keeping up, melting fettling or "fix," and all other requirements, was 3,065 lbs. per ton of 2,240 lbs. of muck-bar. The amount of ore required for "fixing" was 484.52 lbs., of scrap 49.89 lbs., and of scale 53 lbs. per ton of 2,240 lbs. (*Metallurgical Review*, September, 1877.)

The following details of the working of the improved Danks furnaces at Creusot are given by Mr. A. L. Holley: The two Creusot furnaces now make each a ton at a heat, and 20 heats per 24 hours for 6 days, or 12 turns per week. The crude iron is somewhat desiliconized in the premelting open-hearth furnace, and is for this reason easily puddled in half an hour. All the fettling (ore, scale, and a little scrap) is put in cold. The results of one furnace for the first six months of 1878 are as follows:

Number of turns worked	362
" of charges	4,306
Product per turn, lbs.	22,005
" per charge, lbs.	1,850
Consumption per ton of product:	
Pig, lbs.	2,303
Fettling, lbs.	858
Coal for all purposes, lbs.	1,161

The Sellers Rotary Puddling Furnace.—This furnace, somewhat similar in principle to the Danks furnace, is the invention of Messrs. William and George H. Sellers, the inventors of the continuous regenerator heretofore described. It is represented in perspective in Fig. 2452. It is designed to

be used with gaseous fuel in connection with the regenerator. The revolving chamber is open at one end for the reception of the charge and for the withdrawal of the puddled iron, as also for the admission of the flame and the escape of the products of combustion. At the opposite end the vessel is closed by a water-back. The chamber or bowl of the puddling machine when working has its open end in contact with an opening of similar size in the front plate of a stack of flues. Within the circle of the opening in the front plate are arranged the mouths of three flues. The two upper flues carry the gas and the heated air from the regenerators to the rotating bowl, while an opening larger and lower down carries off the products of combustion to the regenerators below the floor. At the two upper openings the gas and air meet, ignite, enter the furnace mouth, and are driven to the back end of the furnace; and then reverberating, they pass back over the surface of the lower part of the bowl, and escape through the down-take, thus filling the bowl with flame. The flue-stack, against which the mouth of the puddling chamber closes, is a rectangular casing of iron, in which are constructed the three flues above mentioned. It is shown in section in Fig. 2453. As plainly shown in Fig. 2452, the rotating vessel can be moved on rollers away from the flue-stack. In the Sellers puddling furnace used by the Edgemoor Iron Company at Wilmington, Del., the charge of pig iron is 1,200 lbs. If the charge is melted in a cupola, it can be puddled in 30 minutes. The blooms weigh about 5 per cent. more than the iron charged, this gain coming from the ore-fettling; the consumption of coal for melting and puddling is about 600 lbs., and the consumption of ore about 400 lbs., to the ton of 2,240 lbs. of blooms.

Siemens's Rotary Puddling Furnace.—The rotary furnace of Dr. C. W. Siemens is similar in many respects to the Sellers furnace. Like the latter, the air and gas enter at the same end at which the products of combustion are discharged, but at the opposite end there is a door through which the charge is entered and the puddle-ball withdrawn. This furnace has already been mentioned under the head of the "Siemens Direct Process," in the experiments upon which it was used.

Crampton's Rotary Furnace.—Mr. T. P. Crampton of Westminster, England, has introduced a rotary furnace somewhat similar to the Sellers and Siemens furnaces, but in which the principal feature is the use of powdered fuel. Coal-dust is blown in at one end of the puddling chamber by an air-blast, and the products of combustion after reverberating come out into a movable chamber at the same end, which forms the door. This furnace is said to be in successful operation at the Woolwich Arsenal. (*Journal of the Iron and Steel Institute*, i., 1873, p. 91.)

Godfrey and Howson's Rotary Gas-Puddling Furnace.—This furnace, which has been introduced in England with successful results, is represented in Fig. 2454. The acting part of the machine consists of a pan-shaped vessel mounted on an axis. This axis is inserted into a long bearing bored out in a framing situated immediately below the pan, a bevel-wheel driven by a pinion being keyed on the axis between the bottom of the pan and the frame. The frame itself is mounted on trunnions which allow of a tilting motion at right angles to its bearings. The shaft of the pinion which causes the revolution of the pan passes centrally through one trunnion, while on the other trunnion a worm wheel is keyed, worked by a worm, through which the tilting motion is effected. It will thus be seen that the pan can be revolved at any angle; its position can be changed through an arc of a circle so as to bring its opening at one time in front of the source of heat, and at another to tilt out the finished ball. The centre of motion is shown in the drawing as situated a little above the bottom of the pan, and the weight of the trunnion frame is adjusted so as to balance the weight of the pan and its contents. The source of heat consists simply of an enlarged gas blow-pipe, the jet from which enters the mouth of the pan centrally or nearly so, while the products of com-

2453.

bustion escape concentrically outside the tuyere and inside the edge of the pan. The gas enters from the main into an annular space just above the tuyere, and the air is forced through a nozzle placed centrally, and perforated with holes. This arrangement is capable of modification, provided only the ordinary blow-pipe conditions are complied with, viz., that the air mixes thoroughly with the gas, and that the focus of most intense heat may be somewhere near the surface of the metal under manipulation. The nose of the outer tuyere is protected from the heat by means of a coil, after the manner of a blast-furnace; but instead of water it is sufficient to allow a small jet of steam to circulate through it, this alternative being designed to obviate the consequences of a leak, which might result in a chance explosion in the pan. The air-nozzle requires no protection. The products of combustion are utilized to heat the air required for combustion, which passes through a series of cast-iron pipes in the upper portion of the stack. The air is thus heated to a temperature of about 800° F.

The operation of the furnace is thus described: "The metal having been melted and transferred by means of a ladle to the puddling furnace, the pan is now revolved at a moderate speed, 10 revolutions per minute being a convenient rate. Assuming that the pan is fairly red-hot before the introduction of the metal, no gas is required. The charge being thus put in motion, the next thing is to

2454.

n the shape of ground oxides, in a
htly heated. Melted fettling is not
The oxides are simply sprinkled
he surface of the metal, which rolls
particles among its mass, and rap-
reby of a thick pasty consistence,
-oxide flames abundantly. It then
temperature, owing to its own in-
tion, and becomes liquid again, but
al appearance. The whole of the
d a granulated condition, swimming
a bath of cinder. The carbon con-
in flames, but without boiling, until
ous, and have a tendency to stick
his point to the end of the process,
tion should not be more than two
l no gas, or very little, is required.
necessary than will keep the cinder
In the course of some minutes the
diminish, and the tendency of the
increases, until at last they collect
ragged masses. An extremely slow motion is now requisite, in order to prevent the formation of crude lumps before the iron has been properly converted. The longer it is kept in a loose and spongy state, the better. As soon as the carbon flames have vanished, or nearly so, a spurt of heat finishes the operation, and the iron may be balled up." (*Journal of the Iron and Steel Institute*, ii., 1877.)

Ehrenwerth's Rotary Puddling Furnace.—This furnace, the invention of Joseph V. Ehrenwerth of Bohemia, is shown in transverse section in Fig. 2455. It consists simply of a revolving hearth fixed on a vertical shaft,

and formed of a cast-iron bottom and flange-plate. The entrance of air to the furnace is prevented by a cylinder of sheet iron, fixed to the hearth or flange-plate, and dipping into an annular trough in which water continually circulates. The heating of the furnace may be done either by an ordinary fire-grate or by gas. When it is charged, the hearth is rotated at the rate of 20 to 24 revolutions per minute, and as soon as the pig begins to melt it is worked about by rabbles provided with "peels" placed obliquely, which are moved either by hand or by engine power. It is said that in one furnace having two working-doors 15 to 20 tons of iron can be puddled at a time. (Blake's "Report on Iron and Steel at the Vienna Exhibition of 1873," p. 50; *Journal of the Iron and Steel Institute*, i., 1875, p. 340.)

2455.

Alleyne's Rotary Puddling Furnace.—Sir J. G. N. Alleyne, Bart., of Derbyshire, England, has a puddling furnace somewhat similar to Ehrenwerth's. It has a rotating bottom of basin form, and rabbles used in connection therewith. The basin is formed with a double bottom, and is supported on a tubular shaft. A pipe extends up this shaft, conveying water to the space between the two bottoms, which keeps the upper bottom cool. The rabble consists of a stem with a number of tines projecting down from it into the fused metal in the basin. (*Journal of the Iron and Steel Institute*, i., 1874, p. 262.)

Pernot's Rotary Puddling Furnace.—The principal feature of this furnace, the invention of M. Pernot, of the works of MM. Petin and Gaudet in France, is an inclined revolving bottom, which, as it rests on wheels, may be kept entirely removed from the furnace. It is illustrated in the article STEEL, which see. A report of the working of this furnace at the works of MM. Petin and Gaudet, in 1874, states that the bottom will hold 1,000 kilogrammes of pig iron per heat, and with fine pig iron 4 or 5 heats may be got out every 12 hours. The balls formed number 17 or 18 at each heat. The record of the working of 290 tons of fine iron and 50 tons of ordinary iron showed:

	Puddling of fine pigs.	Puddling of ordinary pigs.
Charge per 1,000 kilogrammes—pig iron...........	1,021	1,062
" " " coals....	1,379	726

The iron obtained was said to be superior to that obtained from an ordinary puddling furnace, and the waste of iron was much less. The cost prices taken from the books showed a difference in favor of the Pernot furnace as compared with the old system of about 40 francs per ton of 1,000 kilogrammes.

The furnace has been quite extensively adopted on the continent of

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furnace and the chimney or flue during the oscillation, so that the products of combustion may be free to escape. The figure shows a side elevation, with section partly marked. The body of the furnace is supported so as to be free to rock on the bearings B; C is the curved neck, which fits against the chimney D; E is the gearing by which motion is given to the furnace; F is the hearth, which contains the metal being puddled; G are hollow bridges kept cool by air or water passing therethrough; H is the fire-grate; I is the door through which the furnace is charged and the blooms removed; J is the firing-door. After the fettling and cinder are placed in the hearth in the usual manner, the fur-

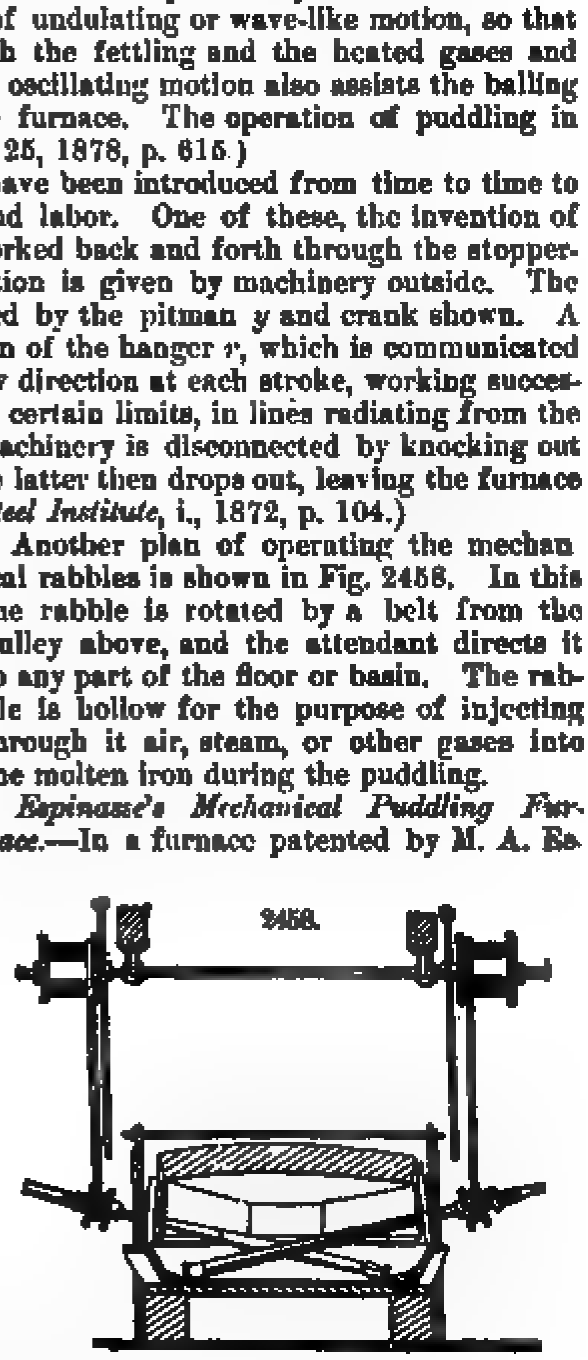
nace is charged with iron, and is then ready for action. The furnace is first inclined so that the heated gases and products of combustion from the fire-grate shall strike directly against the metal in the hearth before passing to the chimney, and thus cause it speedily to assume the molten state. As soon as the metal is in a molten condition, the furnace is caused to oscillate slowly; from 6 to 8 oscillations a minute are sufficient, the greatest angle which the hearth assumes out of the horizontal being about 30°. The oscillating motion causes the iron to flow from one end of the hearth to the other, and strike against hollow bridges provided at each end and kept cool by air or water. The iron while flowing backward and forward acquires a sort of undulating or wave-like motion, so that every portion of the mass is brought into contact with both the fettling and the heated gases and products of combustion passing through the furnace. The oscillating motion also assists the balling if the puddler only takes advantage of the motion of the furnace. The operation of puddling in this furnace occupies from 40 to 60 minutes." (*Iron*, May 25, 1878, p. 615.)

Furnaces with Mechanical Rabbles.—Numerous devices have been introduced from time to time to operate the rabbling tools by machinery instead of by hand labor. One of these, the invention of Mr. John Griffith, is shown in Fig. 2457. The rabble is worked back and forth through the stopper-hole in the door, as in the hand operation, except that motion is given by machinery outside. The rabble v is suspended from the rod r, which is reciprocated by the pitman y and crank shown. A reciprocatory motion is also given to the point of suspension of the hanger r, which is communicated to the end of the rabble, causing the latter to assume a new direction at each stroke, working successively over every portion of the floor of the furnace within certain limits, in lines radiating from the hole in the door. When the iron begins to thicken, the machinery is disconnected by knocking out the cotter that fixes the upper end of the vertical arm. The latter then drops out, leaving the furnace door clear to ball up the iron. (*Journal of the Iron and Steel Institute*, i., 1872, p. 104.)

Another plan of operating the mechanical rabbles is shown in Fig. 2458. In this the rabble is rotated by a belt from the pulley above, and the attendant directs it to any part of the floor or basin. The rabble is hollow for the purpose of injecting through it air, steam, or other gases into the molten iron during the puddling.

Espinasse's Mechanical Puddling Furnace.—In a furnace patented by M. A. Espinasse, and erected at the Firminy Iron Works, France, the puddling apparatus consists essentially of a vertical shaft placed in the centre of the furnace, through the arched roof of which it passes; this shaft, which receives a rotary motion, and may be raised or lowered at will, carries at its lower end two helicoidal wings or blades, which revolve in the bath of molten metal and thus effect the puddling. The results of this furnace are stated to have shown, in comparison with the ordinary type of puddling furnace, an increase in production, a saving in fuel and scrap used, a diminution of waste, and a reduction of nearly one-third in wages. (*Journal of the Iron and Steel Institute*, ii., 1875, p. 672.)

2458.



The Casson-Dormoy Puddling Furnace.—This furnace, which is represented in longitudinal section in Fig. 2459, has been in successful operation for several years at the Earl of Dudley's Round Oak Works, at Dudley, England, and has been introduced in several of the largest English works. It varies from the common reverberatory furnace in having a "gas-producer" in lieu of the ordinary grate; in the puddling chamber being of a perfectly circular form, the sides and bottom plates being so arranged as to expand and contract with the variations in the temperature of the furnace; in having, in lieu of a neck, a chamber for the preparatory heating of the pigs; and in the substitution of mechanical for hand puddling. The gas-producer is constructed similar in form to the Siemens, but instead of the air being heated in a regenerator, it is drawn or blown down the sides of the furnace chimney or flue, and under the bottom crown and walls of the producer, the gases being fired at the bridge; by this means a temperature of about 800° is obtained, and the condition of the furnace is completely under the control of the puddler, who by arranging the blast-valves obtains either an oxidizing or reducing flame, as the condition of the iron may require. The puddling basin rests on a brick pillar 1 ft. 4 in. from the ground. On this is set a wrought-iron circular open dish, with sides about 4 in. deep. Within this dish 8 or more friction-balls, 5 in. in diameter, are placed at equal distances from each other. On these spheres two cast-iron semicircular plates are laid; on these plates

again four side or segment plates are bolted together externally by means of wrought-iron pins, forming a complete circle. Upon these are placed, loosely, the shelf or table plates which, resting upon brackets fixed to the rail buckstaves, support the walls of the furnace. The dish below being kept full of water, the evaporation produced from the heat above cools the bottom and sides, and conse-

2459.

puddling machine is fixed over the furnace, and rests on four old rails, which serve as "buckstaves" on each side of the doors. It is driven by a small double-acting engine, to which it is attached, and the movement is precisely similar to that of the puddler, the rabbles on either side of the furnace being easily changed during the heat. The arms are connected by means of spring driving-rods, which protect the machine from any strain that may be caused by the rabbles.

The furnace is worked in the following way: The preparatory chamber, besides heating the pigs, serves as a neck to the furnace, as soon as the iron is melted. The rabbles, which are so set that they cannot catch into each other in crossing, are fixed to the machine, and worked at a slow motion for about five minutes. The speed is quickened until the iron boils, when the slower speed is put on till the iron drops. The rabbles are then removed, and the real work of the puddler begins, by his balling up the iron in the usual manner. The balls, which are of the ordinary size, are drawn from each door, and the cinder is tapped. A few shovelfuls of hammer-slag are thrown on the bed, and the pigs, which have meanwhile been supplied into the preparatory chamber, are again passed over. These generally melt on the bed in ten minutes or a quarter of an hour. The charges of about 13 cwt usually take from an hour and 20 to an hour and 40 minutes. It will be noticed the iron shields are fixed on each side of the doors between the two buckstaves and about one foot from the ground floor. It is found that the heat of the upper portion of the furnace induces a constant circulation of cold air between the casings thus formed, and the surface of the brick walls protects the puddler when the door is drawn up to pull out the balls. (*Journal of the Iron and Steel Institute*, i., 1876, p. 109.) W. K.

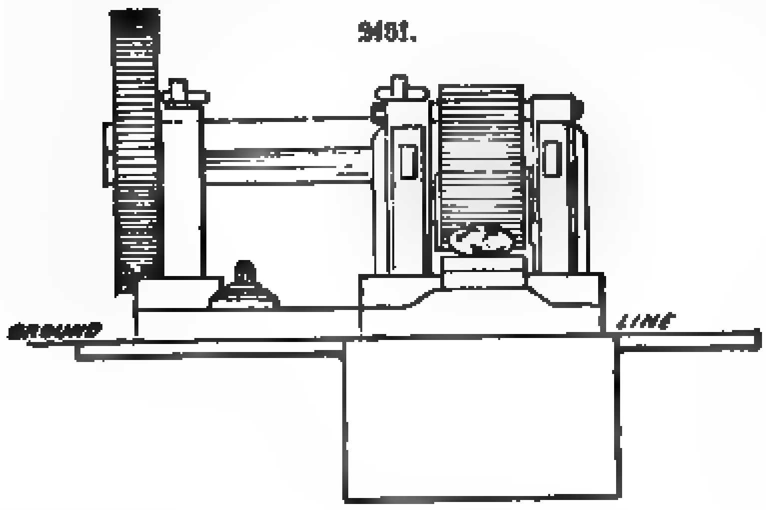
IRON-WORKING MACHINERY. Treatment of the Puddled Ball.—The ball as it leaves the puddling furnace is a spongy mass, consisting of particles of iron feebly cohering, with fluid cinder filling the interstices between them. To compress the ball into a solid lump, and to expel the cinder from it, it is shingled, as it is called, either under a hammer worked by steam- or water-power, or in a squeezer. (See Hammers.)

Squeezers.—One of the earlier forms of squeezer, known as the crocodile squeezer, is shown in Figs. 2460 and 2461. It will be easily understood from the engravings without any description. The upper jaw alone is movable, and it is ribbed or serrated on its under surface, where it comes into contact with the ball. The ball, as it is compressed by the repeated downward movement of the upper jaw, is placed nearer and nearer the axis. The crocodile squeezer has been almost entirely superseded by Burden's rotary squeezer, invented by Mr. Henry Burden of Troy, N. Y., which is shown in perspective in Fig. 2462. It consists of a strong cast-iron wheel, with its axis vertical, and ribbed or serrated on its face, which revolves eccentrically within a strong cylindrical cast-iron frame serrated on its inner surface. The ball is entered at the left-hand side, where the opening between the wheel and frame is about 15 in. wide, and by the revolution of the wheel is carried round to the place of exit on the right, where the opening is only about 7 or 8 in. wide. The ball as it enters the squeezer is an irregularly-shaped mass, approximately spherical, from 10 to 15 in. in diameter, and it emerges compressed into cylindrical form 7 or 8 in. in diameter and 12 or 15 in. long. The two

hinged bars shown at the right hand of the perspective view act as a tripping apparatus to throw the ball out from the wheel and upon the plate in front.

An excellent form of squeezer, invented by Mr. Winslow of Troy, is in use at the works of Messrs. Graff, Bennett & Co., of Pittsburgh, for compressing the large 900- or 1,000-lb. balls made in the Danks puddling furnace. It consists of two horizontal rolls, about 2 ft. in diameter and 5 ft. long, placed side by side, with serrated surfaces, and, above these, with its axis parallel with and above the line between them, a heavy eccentric roll or cam, with a throw of about 2 ft., its surface also serrated with the exception of a portion farthest from the axis. The rolls and cam are driven by geared wheels. The ball, an oblong mass about 26 in. in diameter and 3½ or 4 ft. long, is placed on the horizontal rolls, which revolve in one direction, and the cam is slowly rotated, and compresses the ball to an almost perfectly cylindrical form, while on one end it is rapidly struck by a steam-ram placed at the end of the squeezer, in a line with the axis of the squeezed ball. The cam is rotated twice, and the ball when taken out is thoroughly compressed into a well-formed cylinder 18 in. in diameter and about 3½ ft. long. The ball after leaving the hammer or squeezer is at once, usually without reheating, taken to the rolling-mill or roughing-rolls. This consists of massive grooved rolls connected by toothed pinions, and put

2451.



2452.

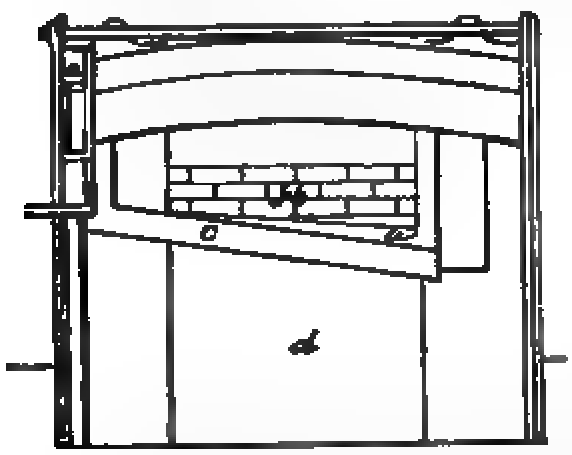
in motion by the steam-engine. The rolls are fixed in heavy framings or "housings," which have to support a tremendous strain as the ball is passed through, compressed, and elongated. The rolls

2453.

move continuously in one direction, and the bloom is passed between them in one direction, and back over the upper roll in the reverse direction. The bar so formed is passed, in the ordinary

method of treatment, through a succession of grooves gradually diminishing in size, until it is reduced to a bar about 4 in. wide, three-quarters to one inch thick, and 12 or 15 ft. long. This is known as puddle-bar or "muck-bar." The grooved rolls for working iron were invented in 1783 by Henry Cort, the inventor also of puddling. That rolls without grooves, for making plate metal, were not invented by Cort at the same time, as is frequently stated, but were a prior invention, is shown by a passage in Boswell's "Life of Johnson." In the diary of his Welsh tour, Aug. 3, 1774, when at Holywell, Johnson says: "At a copper work, which receives its pigs of copper, I think, from Warrington, we saw a plate of copper put hot between steel rollers, and spread thin· I know not whether the upper roller was set to a certain distance, as I suppose, or acted only by its weight. At an iron work, I saw round bars formed by a notched hammer and anvil."

2464.



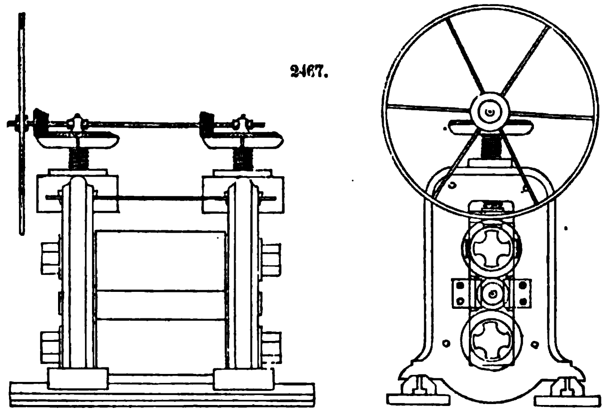
The puddle-bars are taken when cold to the shears (see PUNCHING AND SHEARING MACHINERY), cut and piled into a second bloom, or "pile," as it is then called, the size of which depends upon the size of the iron desired to be made, and upon its intended use, reheated in a reverberatory furnace, and rolled in the finishing-rolls to the required shape. Sometimes this piling, reheating, and rerolling is done several times, in order to increase the density and strength of the iron, and more thoroughly free it from cinder, for

heat of the furnaces is utilized in heating the air used for the combustion of the fuel on the grate-bars. At the bottom of the stack or chimney there is a square opening, and above it are several perforations in the brickwork, through which the air enters and passes into flues surrounding the base of the stack, where it becomes heated by contact with the sides of said flues. It is then conducted round the neck of the furnace into a series of parallel horizontal passages under the bed, whence it enters the opening under the fire-bars, and reaches the fire at a high temperature. The furnace has also been advantageously adopted for puddling. (*Journal of the Iron and Steel Institute*, i., 1872, p. 182.)

ROLLING-MILL MACHINERY.—The squeezers, and the common form of rolling-mill, or "two-high" train, as it is called, have already been described. In the two-high train, one or more pairs of rolls are connected together, and the piece of metal requiring to be rolled is passed alternately between and over the pair, the operation being repeated in successive grooves until the iron is reduced to the required size. The rolls present three distinct parts: the body, the necks or journals, and the ends or "wabblers." The different sets of rolls are connected together by spindles and coupling-boxes. The wabblers and the ends of the spindles are grooved, and the coupling-boxes fit loosely over them, allowing a play of about one-eighth of an inch. The rolls are

supported between chucks inclosed in the housings. Each housing is supplied with a large screw. These screws, which pass through large nuts fitted to the caps of the housings, press on the chucks above the upper roll, and serve to hold them in position. In order to facilitate the entering of the bar in the various grooves, wrought-iron pieces called rests are placed in front of the rolls, nearly but not quite at the height of the bottom of each groove. On the side of the rolls where the iron leaves the grooves are placed other pieces called guides, with grooves in them to direct the iron from the rolls. In the smaller sizes of rolls, or finishing-rolls, guides instead of rests are placed in front of the rolls, which are then called guide-rolls.

2467.



One of the most important improvements in rolling-mill machinery has been the introduction of the "three-high mill," in which three rolls are placed one above the other. In this arrangement the middle roll turns in a contrary direction to the other two. The loss of time, and in heavy rolling the waste of labor, in returning the bar over the top roll by the common system of rolling in the two-high mill, is completely avoided in the three-high mill, which reduces in both directions. The three-high mill has come into most extensive use in the United States.

For rolling plate, the three-high mill invented by Mr. Bernard Lauth of Pittsburgh, shown in Fig. 2467, is largely used. In this the middle roll is much smaller than the upper and lower rolls. The smaller a roll for rolling plate, the less the power required for a given reduction, since the portion of the plate acted upon at each instant is smaller; but when the rolls are made small enough for economy of power in this regard, they are apt to spring, from the immense pressure brought to bear upon them; the top and bottom rolls are therefore made heavy in order to receive the strain transmitted through the middle roll and prevent the bending of the latter.

The handling of the iron, as it is being transferred from one groove to another, or from the upper to the lower roll and *vice versa*, is usually done by workmen with long hooked levers, the fulcrums of which are suspended by long rods from the roof framework overhead. For handling very heavy masses machinery is used to a greater or less extent. One of the most complete appliances for this purpose, in connection with the three-high mill, is the "blooming-tables" invented by Mr. George Fritz of Johnstown, Pa. The tables, one on each side of the rolls, are lifted and lowered by hydraulic power, and each table consists of a series of rollers which are set in motion every time the iron comes upon them, by an arrangement of friction and cogged wheels, for the purpose of carrying the iron into the various grooves. These tables are universally used in the Bessemer steel works for handling the heavy ingots in the blooming-mill. An automatic lifting-table for the same purpose, the invention of Mr. Charles Hewitt of Trenton, N. J., and used at the Trenton Iron Works, was described by Mr. William Hewitt in the *Iron Age* of Dec. 2, 1875. It is operated by the weight of the iron descending from the upper roll to the lower, which raises a set of counterweights, whose weight is afterward applied to lift the iron from the lower roll to the upper, the distance through which the iron is lifted on the tables being somewhat less than that through which it descends.

In England, instead of the three-high mill, the reversing two-high mill is more generally employed. In this mill the direction of the rolls is reversed after each passage of the iron. The common method of reversing the rolls at present is by means of five spur-wheels, two of which are on the same axis and run in opposite directions. To each of these wheels is attached a clawed clutch, the claws of which are placed in opposite directions; and into each of the claws is moved alternately a clutch, which slides upon feathers fixed to the main shaft. The centre clutch is moved into either of the side clutches before the bloom, plate, or bar is allowed to enter the rolls, and at the time of the entrance of the centre clutch the side clutches are moving at full speed while the centre clutch and rolls are stationary. The starting is therefore effected by a blow, the violence of which depends upon the speed and weight of the moving parts. Several improvements have been devised for avoiding this sudden shock, of which space will not allow treatment here. Reference may be made to the *Journal of the Iron and Steel Institute*, May, 1871, and August, 1872; *The Engineer*, May 13, 1870; *Engineering*, Aug. 3, 1866, May 9, 1873, and March 13, 1874; and the *Metallurgical Review*, February, 1878, p. 505. One system of reversing a two-high mill, which dispenses with the use of a clutch, consists in the use of a reversing engine, first adopted by Mr. Ramsbottom of Crewe. A two-cylinder engine is used, and it is reversed by the ordinary locomotive reversing links; but instead of the hand-lever for reversing, a steam or hydraulic cylinder is employed. The sudden stopping and reversing of the rolls is effected by admitting steam- or water-pressure to the small cylinder which reverses the link; this, operating the main steam-valves of the engine-cylinders, admits steam in front of the pistons, on which the latter cushion, causing the engine at the will of the attendant either to stop or to move in a reverse direction.

An adaptation of this reversing engine was in 1878 adopted by Mr. Andrew Kloman of Pittsburgh, for rolling blanks for eye-bars, for bridges, and similar work in which it is required that the ends

of the bar shall be left of a larger section than the middle portion. He uses a two-high universal mill (see below), with a roller-feeding table on each side. The bar is reversed to and fro as in the ordinary two-high mill until it is reduced to a section equal to that required for the two ends, and then slowly passed through the rolls to the point at which it is desired that the reduced middle portion shall taper into the larger section of the ends. The engine is reversed at the precise instant necessary, and the bar rolled in the reverse direction until the point of change of section at the other end is reached, when the rolls are again reversed, and the operation continued until the middle portion is reduced to the required size. The lower roll (which is moved vertically by a hydraulic cylinder placed beneath it) is then lowered, and the bar is withdrawn by the feeding-tables.

The Universal Mill.—This mill derives its name from the facility which it affords for rolling different widths and thicknesses with the same set of rolls. Mr. William Hewitt says: "Mr. Isaac Dreyfus of Paris claims to be the inventor of this mill, but we think that he was anticipated by Messrs. Hartupee and Alexander of this country (see *The Engineer*, June 14, 1861, and the Patent Office Report for 1853, p. 176.)" It consists, as described in *Engineering* of May 24, 1876 (as the invention of Mr. Wagner of Austria), of two horizontal rolls, mounted and geared in the usual way, and a pair of vertical rolls, fixed in bearings which can be traversed on slides in a horizontal direction by means of a pair of right and left screws. The simultaneous movement of the two screws is obtained by a hand-wheel geared to a vertical spindle carrying two worms, which act upon wheels keyed on to the screw-spindles. By turning these spindles the two vertical rolls are brought closer together or removed from each other, and by these means the width of the bars to be produced in the mill can be fixed at will. The spacing of the horizontal rolls is secured by screws in the upper part of the housings in the ordinary way. When the mill is used as a reversing mill, as is usual, a pair of vertical rolls is placed on each side of the horizontal rolls. A mill of this kind is in use at the Millvale Works of Graff, Bennett & Co., near Pittsburgh, for reducing the bloom of Danks iron after it comes from the Winslow squeezer described above. The cylindrical bloom, 13 in. in diameter and about 3½ ft. long, is reduced in 10 or 12 passes to a muck-bar plate 25 to 30 ft. long, 12 in. wide, and seven-eighths of an inch thick. A three-high universal mill has been erected at the works of the National Tube Works Company in McKeesport, Pa. In this mill the reversing of the engine is dispensed with, and the lifting of the iron from the lower to the upper rolls substituted.

The Continuous Mill.—The continuous mill consists of a consecutive series of rolls, each with one groove, one pair in front of another, so placed that the piece to be rolled passes from one pair directly to the next pair, and so on to the last pair, being partially reduced by each. As the bar decreases in sectional area the velocity of the rolls increases, the last pair moving with the greatest velocity. This mill is now largely used for the rolling of wire rods. The arrangement of the rolls varies. In all it is necessary to so place the grooves that the fin formed on the bar by one pair of rolls shall be rolled down by the next pair. This is accomplished sometimes by having the pairs of rolls alternately placed horizontal and vertical, or by having the axes of each pair inclined at angles which alternate with each other, or by turning the bar as it passes from one pair to the next. A continuous mill for rolling wire rods, invented by Mr. George Bedson of Manchester, England, consists of a long series of rolls placed in pairs, alternately horizontal and vertical, each pair having one groove, through which the wire passes, and is delivered to the next pair, reduced in section and extended proportionately in length. The gearing is so arranged as to give a higher speed to each successive pair. In the course of the operation one part of the billet is within the furnace, while another part is being coiled up at the other end of the mill in the form of wire. (Osborn's "Metallurgy," p. 816.)

Another form of continuous mill, invented by Jeremiah Brown (British "Specifications of Patents," A. D. 1868, No. 2,501), is thus described by the inventor: "It consists in arranging two series of rolls, one in advance of the other, each of the series consisting of four or more rolls. The rotation of each series of rolls is in a direction opposite to that of the adjacent series. Thus, when I employ two series, each consisting of four rolls, I arrange them in the following manner: The first pair of rolls rotates in a direction proper to take the bloom or slab or pile from the workman, and after having passed through the said rolls to deliver it to the second pair, immediately in front of the first pair, having rotation in the same direction, but sometimes driven at a higher speed than the first pair. The bloom or slab is now returned through a third pair, the axes of which are in a line with the axes of the second pair, but which third pair rotates in a direction opposite to that of the first and second pairs. The bloom, pile, or slab is delivered by the third pair of rolls to a fourth pair, whose axes are in a line with the axes of the first pair, and which rotate in a direction similar to that of the third pair. The slab, pile, or bloom, having thus passed through four pairs of rolls, is delivered back to the workman on that side of the system of rolls from which it was introduced."

Still another modification of the continuous mill is that known as the "open-face" system, in which the consecutive pairs of rolls are placed not one in front of another, but side by side in line with each other. The alternate pairs are so geared as to rotate in contrary directions. The billet or rod is introduced into the first pair, and a workman rapidly catches the end as it emerges on the other side and enters it into the second pair, on the other side of which another workman catches it and enters it in the third pair, and so on, the rod sometimes being in five or six pairs of rolls at once. The rolls increase in velocity, each over the next preceding; and the last roll is sometimes run so fast as to give the rod as it emerges a speed exceeding 1,000 ft. per minute. An improvement recently made in the continuous mill for wire is the introduction of a curved guide of U-shaped section, reaching from one groove to the next, through which the rod is run, thus dispensing with the workman at each groove. The perfection to which this type of mill has been brought for wire purposes is extraordinary. One such mill recently (November, 1878) is said to have rolled 54,820 lbs. of No. 4 wire in 9 hours. The continuous mill has been introduced also for the rolling of hoops, and is likely soon to be applied in one form or another for many other purposes.

The rolls commonly used in iron works turn out round bars in a rough state, and only approximately straight. They may be straightened by the ordinary straightening machine, which consists of one or more pressure-screws or cams operated by any convenient mechanism, by which pressure is brought successively on the various parts of the bar which are out of line. This is a very rough contrivance, and requires a considerable amount of labor to operate it. Several improved machines for rolling or straightening bars or tubes which are very much superior to the old forms will be described.

2468.

Lauth's Straightening Machine.—This machine, made by Mr. Bernard Lauth, as seen in Fig. 2468, consists of five rolls, three lower and two upper, with grooves corresponding to the section to be rolled and straightened. Any of the ordinary sections, such as rods, bars, rails, beams, or angles, may be straightened in this machine. Three of the rolls, two lower and one upper (and between the two), are so spaced that the piece to be rolled, if perfectly straight, will fit exactly between them. The other two, which are on the entering side, are also so spaced that the piece may be entered between them, but are so placed with reference to the other three as to give the bar or piece a very slight bend as it goes from the two to the three. This takes out any bend which may previously exist in the bar, replacing it by a slight bend always in the same direction, which the three rolls remove.

Reese's Conical Disk-Rolls.—This machine, invented by Mr. Jacob Reese of Pittsburgh (patents 65,832, June 18, 1867, and 190,983, May 22, 1877), is used for rolling and straightening cylindrical bars or tubes. The disk-rolls have slightly conical faces, and are arranged with the apex of one cone opposite the circumference of the base of the other, the opposite faces of the rolls being parallel. These disk-rolls are caused to revolve in the same direction by means of the gearing, and consequently the surfaces of the rolls opposite each other will move in opposite directions, while the movement imparted to a cylindrical bar or tube (in the line of its axis) passing between the disk-rolls will be in one direction when the bar is above a line drawn through the axes of the rolls, and in an opposite direction when below this line. A movable rest is arranged between the rolls, and parallel to the operating faces thereof. In the operation the disk-rolls are adjusted by means of screws to

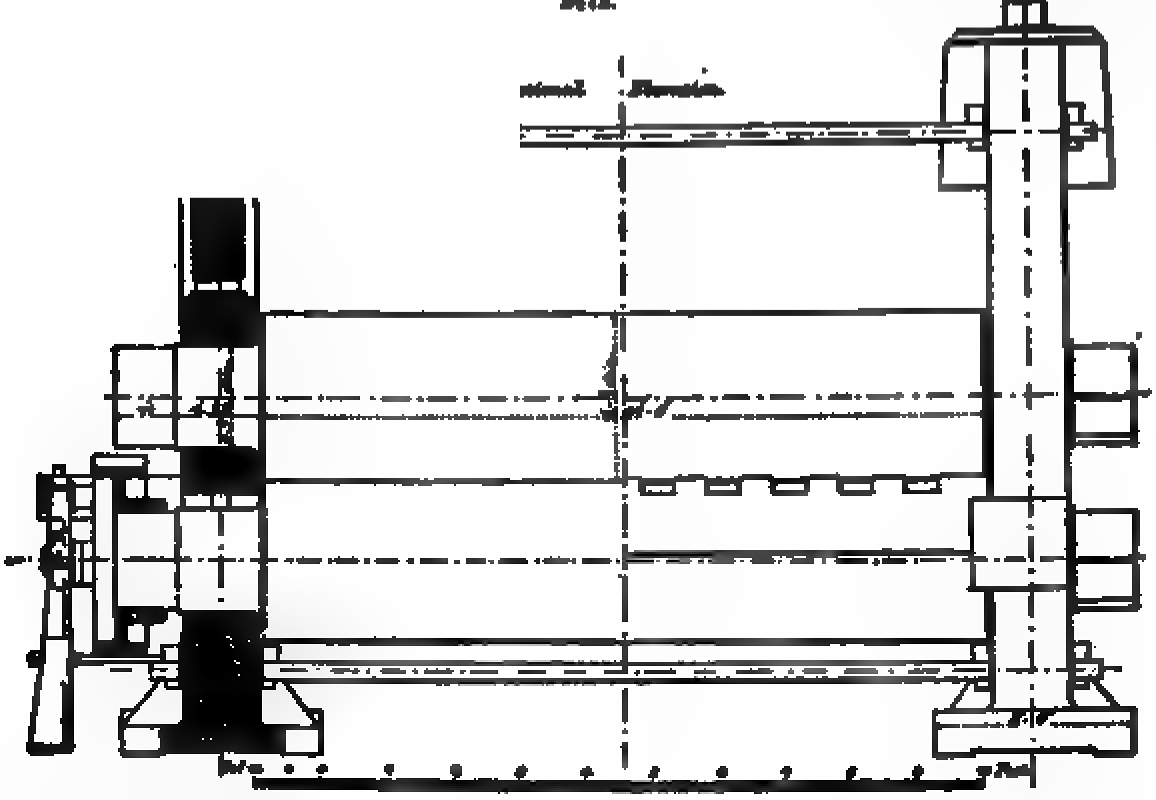
2469.

suit the diameter of the bar or tube to be rolled or straightened. The rest is brought to its lowest position, the rolls are revolved, and the cylinder is seized by the rolls, one of which works with a downward motion on the line of bite, and the other with an upward motion, imparting to the bar or tube a rotary motion on its axis, and at the same time a forward motion in the line of its axis. As soon as it is desired to reverse the direction of this latter motion, the rest is moved until the bar is brought above the centre of the rolls, when, while it continues to rotate on its axis, the forward motion in line with its axis is reversed, without reversing the rolls. The speed of the motion in the line of its axis will also vary with the distance the bar is above or below the centre of the rolls; when at the centre this motion will cease. The highest speed is about 400 ft. per minute. When it is desired to reduce the bar while in the rolls, the screws are turned so as to bring the faces of the rolls closer together, and thus the cylindrical bar or tube may be rolled, reduced, and straightened by a single workman and in one continuous operation. One of these mills is in use at the steel works of Messrs. Benjamin Atha & Co. in Newark, N. J., rolling steel rods, and one has recently been built for the Cleveland Rolling-Mill Company (1879).

2471.

Seaman's Rounding and Straightening Machine.—This machine, invented by J. S. Seaman of Pittsburgh (patents 155,760, October 6, 1874, and 192,460, November 28, 1876), is shown in Fig. 2469. It consists of four collared or grooved rolls, two placed side by side (separated by a space which is adjustable), and two one above the other, directly above the line between the two side rolls. The axes of the upper and lower rolls are parallel; the axes of the two side rolls are parallel in their vertical planes, but their horizontal planes cross at a slight angle, one being raised above the other at one end, the second being raised above the first at the other end. The two side rolls revolve in one direction. The bar to be rolled is passed into the quadrangular-shaped space between the faces of four rolls, and the surfaces of the side rolls touching it and rotating in contrary directions cause it to rotate.

2472.



The angular motion of the collars of the side rolls, caused by the obliquity of their axes, produces a forward motion in the bar to be rolled, and thus it is passed through from one end to the other. The upper and lower rolls act merely as guides to keep the bar in place between the side rolls. Any pressure that may be desired may be brought upon the bar by the side rolls, and as it leaves the

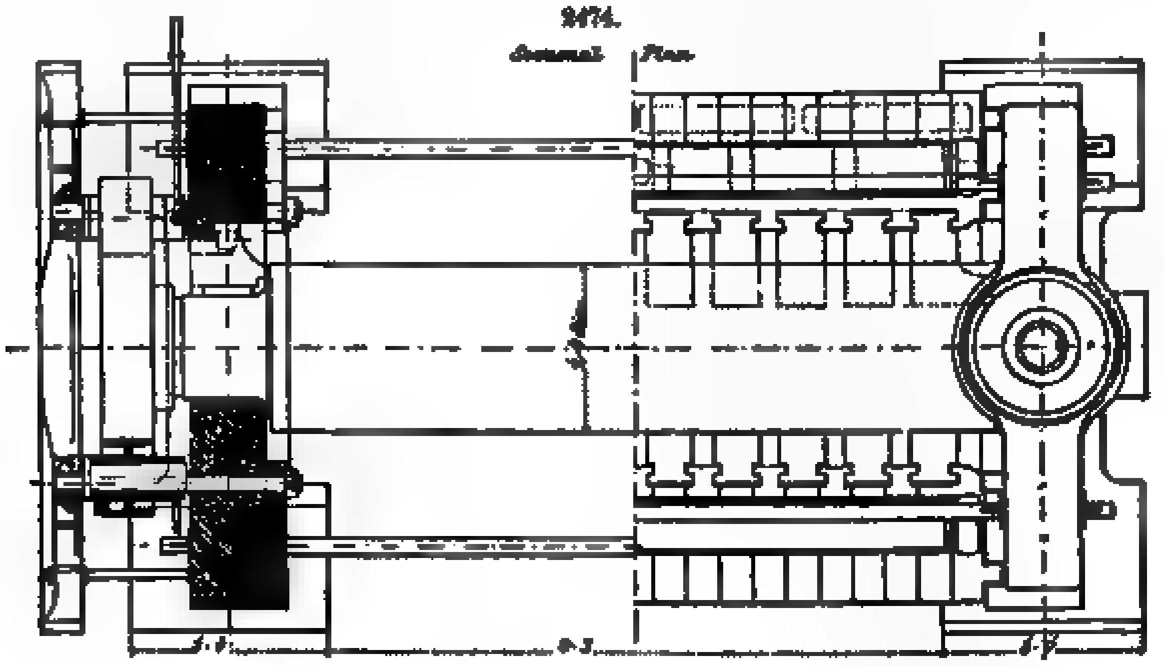
2473.

machine it is rounded, straightened, and polished. Twenty of these machines were said to be in use in various mills in 1878.

Bending Rolls.—This description of machine is employed to bend plates or other pieces of metal at any desired curvature or circle within the limits of the capacity of the machine. In the improved bending machine shown in Fig. 2470, Messrs. Sellers have arranged two pinching-rolls, one directly over the other, both being driven. The bending-roll is placed to one side of the lower roll, with the housings so made as to guide the bending-roll diagonally past the lower roll toward the upper one, as shown in Fig. 2471, in which the top roll A is placed directly over the bottom roll B. C is the bending-roll, adjustable toward A in the direction of the diagonal dotted line. When roll C is down far enough to have its top level with the top of roll B, then a plate, $D\,E$, can be passed between rolls A and B without being curved; but when C is raised toward the position indicated by the dotted circle C', then the plate will be curved. The pinching-rolls are geared together to insure that they revolve in proper relation one to the other, and thus avoid any calendering motion on curved plates. To enable the removal from the rolls of plates bent to a full circle, the top roll is made to tilt at one end.

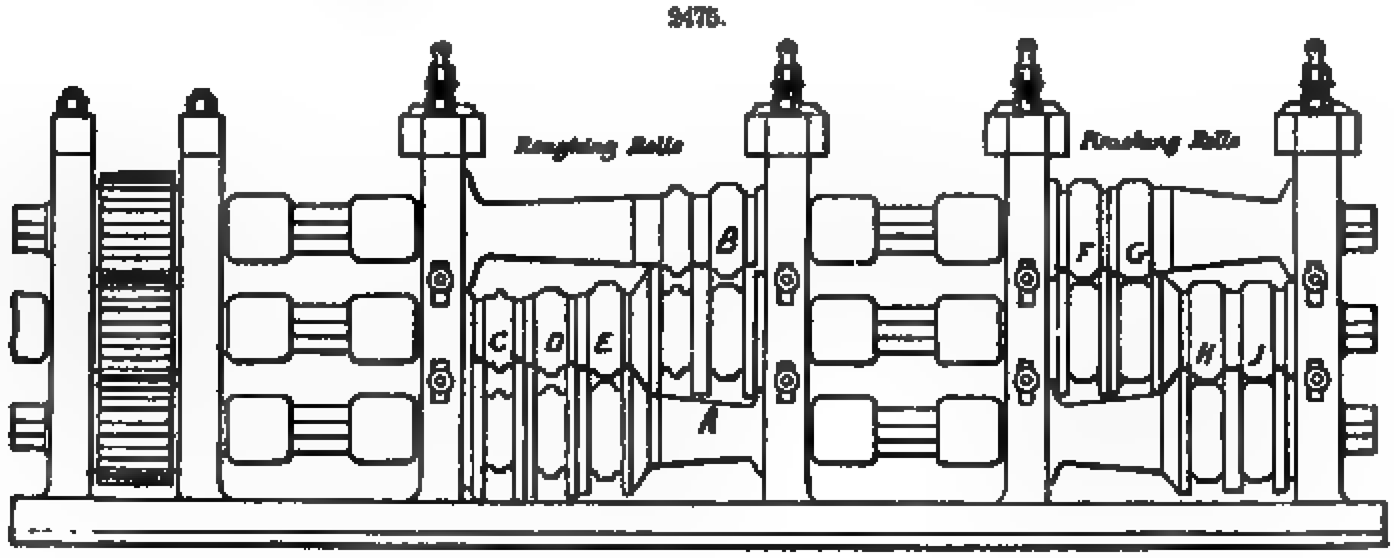
Plate-Rolls.—In Figs. 2472, 2473, and 2474 are represented the rolls used by one of the largest boiler-plate mills in the world, that of the Farnley Iron Works near Leeds, England. The rolls are 31 in. in diameter and 11 ft. long, and are driven by a

2474.



pair of engines with 50-in. cylinders and 4 ft. stroke, geared 2.88 to 1 to the rolls. Plates 10 ft. or 10 ft. 6 in. wide can be rolled. The screws for adjusting the rolls are 9 in. in diameter and 1 in.

2475.



pitch, and they are worked by ordinary spanners (not shown) having a radius of 4 ft. and 16 arms. The feet of the housings are planed where they rest on the bed-plates, and the holes for the screw-

bushes bored. Holes are also cast in the housings for the balance-pillars to pass through, and the latter are cottered into the chocks as shown. The arrangement for traveling the slab or plate forward into the rolls consists of a roller 9 in. in diameter traversing nearly the whole length of each plate (front and back), as shown in the half plan and cross-section, Figs. 2473 and 2474, this roller being supported in the middle of its length by a friction-roller. On the outer end of the bottom (main) roll is keyed a plain friction-roller 2 ft. 9 in. in diameter and 9½ in. wide, and on the end of each 9-in. roller-spindle (which passes through the body of the housing, and is carried by the outer bearing) is keyed another roller 15 in. in diameter; between the two rollers mentioned a third roller revolves loosely on an eccentric shaft, as shown in the end elevation, Fig. 2474, this roller being forced into contact with the other rollers by means of the lever shown, and thus giving motion to the rollers in front and back plates and traversing the slab or plate as required. This arrangement has been found to work well. The front and back plates are each in one casting, and drop into recesses formed on the inside faces of the housings; deep pockets are cast for the guards to drop into, the latter being notched as shown on the plan. Among other heavy work turned out by it were eight plates measuring 10 ft. 2 in. by 9 ft. 10 in. in area, manufactured for Messrs. Key of Kirkcaldy. These plates were made from slabs from 4¾ in. to 5 in. thick, and were rolled out to the required dimensions in 34 passes, the average time required being 7 minutes, and the pressure of steam used being 50 lbs. per square inch. More recently other plates of similar dimensions have been rolled out by 35 passes in 5¾ minutes; and it is expected that with further practice in handling these heavy slabs, this time will be reduced to 5 minutes. In all the above-mentioned cases the plates have been successfully rolled off without any hitch whatever.

2474.

Rail-Rolls.—Fig. 2475 illustrates some improvements in rail-rolling mills described by Mr. A. Thomas in a paper read before the Iron and Steel Institute of Great Britain (1877), which consist in the suppression of all the usual double collars, and in the casting of the top roll with grooves on one-half of its length only, while the remainder is left plain and made conical; or, if grooved all along, this latter half is destined for use in another train, or, if preferred in the same housings, by reversing the roll. The bottom roll is also cast with grooves on one-half of its length only, the remainder being left taper or conical, or this latter half is done away with altogether. The middle roll carries grooves on one half of its length, and ridges on the other half, all the grooves which roll in the same direction being placed next to each other, while in the ordinary system the grooves and ridges alternate, the neighboring grooves rolling alternately in inverse directions, which causes the necessity for the double

collars between the grooves. The top and bottom rolls, when cast with conical ends, are left quite in the rough on this useless portion, in order to economize cost of material. The lower roll, from the same motive, is generally cast hollow. In this mill, the bar or ingot or bloom is first passed through the roughing-rolls, in the following order, as shown in the drawing: first between the middle and bottom roll, at *A*; then between middle and top roll at *B*; and successively through *C*, *D*, and *E*. From this the bar is carried at once to the finishing train, and passes successively through grooves *F*, *G*, *H*, and *I*. Such a disposition gives very great facilities for the rolling of all kinds of profile, angle, and T iron, and rails; and no difficulty whatever is experienced in producing lengths of 80 ft. in one single heat, and without need of flat bars in the piling. Experience has demonstrated an economy of from 40 to 100 per cent. in the weight of castings needed for the rolls, as compared with the older kind, joined to 100 per cent. of economy in the turning and repairing of the same.

Stretching and Straightening Machine.—In Fig. 2476 is represented an ingenious machine for straightening bars devised by Mr. S. W. Baldwin of Yonkers, N. Y. On the main shaft, driven by the large belt-pulley shown, are pawls which engage in a rack on a carriage which slides in ways on the bed of the machine. At the rear end of the carriage is a screw-clamp. Extending across the bed are numerous horizontal cross-ribs, on which the bar after it comes from the rolls is placed. One end of the bar is secured in the clamp on the carriage, and the other extremity is fastened in another clamp shown in process of adjustment by the workman on the left. This clamp travels on wheels running on a rail beside the bed, and may be adjusted and secured in any desired position. On the power being communicated to the main pulley, the pawls on the shaft are caused to engage in the rack, and so move the carriage to the right (as shown in the engraving), thus stretching and at the same time straightening the bar. As soon as this operation is completed, the clamps are loosened, and the bar is moved over to one side of the bed, where the cross-rails are inclined, and here it is left to cool. The carriage may be quickly returned to its original position by hand. The machine is strongly built, and has been put into successful use in large iron works.

Cold Rolling.—This process, patented by Mr. Bernard Lauth in 1859 (patent No. 25,235, Aug. 23, 1859), consists in passing rods or bars in a cold state through the rolls, reducing them very slightly at each pass. The result of this treatment is to strengthen the iron, and at the same time give it a finished appearance. Ordinary wrought iron, by being cold-rolled, may have its ultimate strength increased as much as 50 per cent. or even more, the amount of strengthening depending upon the amount of reduction, which however must not be carried to too great an extent, as the bar is thereby weakened. The elastic limit of the bar may be increased by cold-rolling more than 100 per cent. The ductility, however, is decreased, and in general the effect is to give the iron the qualities of hard steel. Cold-rolling has been applied principally to shafting, and to the finger-bars of mowing machines, for which purpose it has been used very extensively by Messrs. Jones & Laughlins of Pittsburgh. It is gradually being adopted for many other purposes. (*Metallurgical Review*, September, 1877, p. 13.)

Works for Reference.—Under many of the subjects treated of in this article, and the articles on IRON-MAKING PROCESSES, are inserted references to publications in which detailed accounts of these subjects will be found. For a description of iron-making methods and apparatus used prior to 1864, by far the best general work in the English language is Percy's "Metallurgy of Iron and Steel" (London, 1864). The works of S. B. Rogers, Overman, Bauerman, Fairbairn, Kohn, Crookes and Rohrig, and Osborn may also be consulted. For the more recent literature of iron-making recourse must be had to the periodicals. The most valuable publication of this kind is the *Journal of the Iron and Steel Institute* of Great Britain, established in 1869. In this will be found original papers on nearly all branches of the modern metallurgy of iron; and it is especially full on the subject of the new puddling furnaces. A few valuable papers are to be found in the *Transactions of the American Institute of Mining Engineers*, the *Journal of the Franklin Institute*, and the *Metallurgical Review*. Papers on iron-making are also constantly appearing in the English weekly engineering and iron-trade journals, chief of which are *Engineering*, *The Engineer*, *Iron*, and *The Iron and Coal Trades Review*, and in the American weeklies, the *Iron Age*, the *American Manufacturer and Iron World*, and the *Engineering and Mining Journal*. W. K.

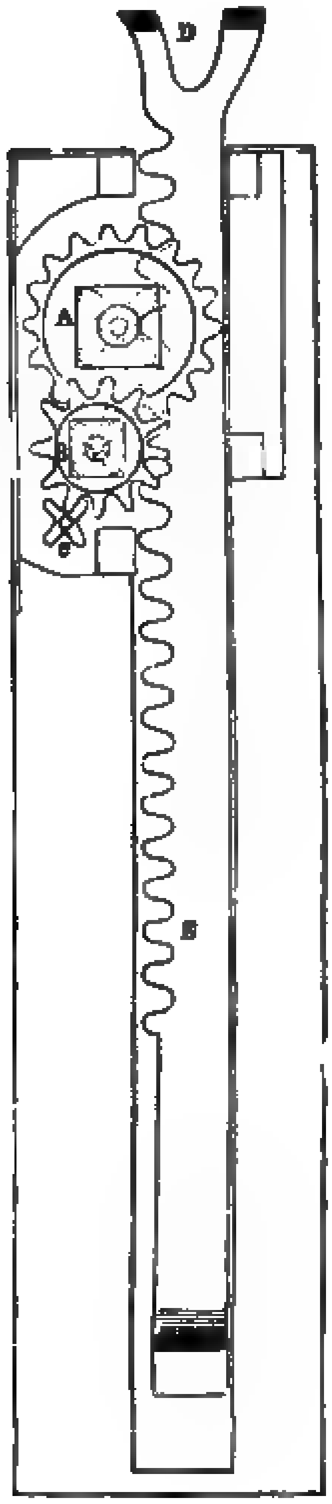
JACKET. Most commonly an outer case or envelope, usually of non-conducting material, designed to prevent radiation from the vessel inclosed. Steam-cylinders are often provided with a jacket of live steam circulating in the annular space between the cylinder itself and an outer casing, the object being to prevent radiation from the cylinder. Cylinders of air-compressors, on the other hand, often have jackets of circulating cold water, which reduces the temperature of the air heated by compression. (See AIR-COMPRESSORS.) Evaporating pans are sometimes heated by a steam-jacket; and steam-boilers are jacketed with felt to prevent radiation.

JACK-PLANE. See PLANES.

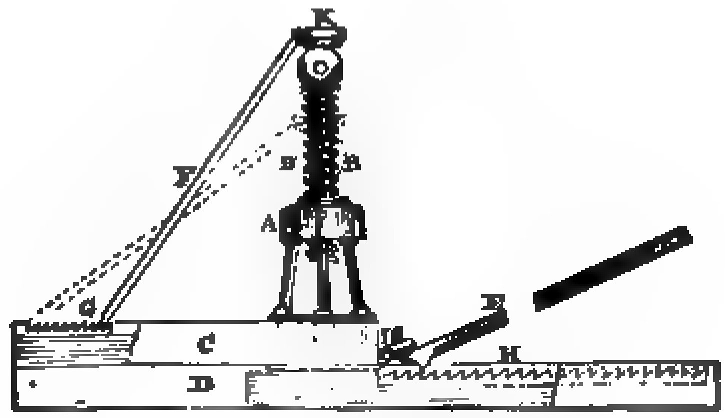
JACKS. Mechanical devices for raising heavy weights. A jack often consists of a small pinion worked with a common winch. This pinion works in the teeth of a large wheel, on whose axis there is fixed a small pinion with teeth, working in a rack. The turning of the handle raises the rack, and of course any weight attached to it. If the length of the handle of the winch be 7 in., and the pinion which it drives contain 4 leaves, working in the teeth of the large wheel having 20 teeth, then will 5 turns of the handle be requisite for one of the wheel. But the length of the arm of the winch being 7 in., the circumference through which the handle moves will be about 44 in., and for one turn of the wheel the handle must pass through $5 \times 44 = 220$. The wheel carries a pinion of, say, 3 leaves, of a pitch of one-third of an inch, working the rack that carries the weight; one turn of the pinion will, therefore, raise the rack one inch, and as the power moves through 220 in the same time, 220 will be the power of the jack.

Fig. 2477 represents a plan of a jack-screw for turning large stone.

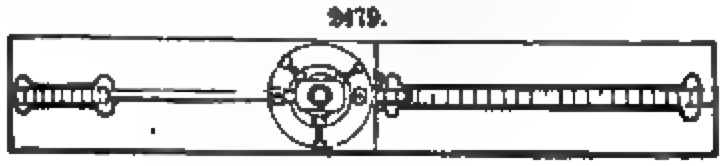
2477.



2478.



2479.



2480.

2481.

2482.

Figs. 2478 and 2479 exhibit a side view and plan of a traversing screw-jack. The screw-jack A is bolted to the plank C; at the other end of the plank is fixed the rack G, in which the toe of the strut F advances as the screw B is elevated; the strut works in a joint in the follower K: the position of the strut when the screw is depressed is shown by the dotted lines. The object of this strut is to relieve the screw of the violent cross-strain to which the apparatus is subject, when the engine or carriage is pulled over by the lever; which strain is entirely transferred to the strut, and the screw has merely to carry the load. The operation of traversing the jack is by hooking the link I upon the hook of the lever E, the toe of the lever being inserted into a ratchet of the rack H of the lower plank, when a man bearing down the end of the lever drags the apparatus and engine or carriage toward him with great facility; the same lever is used to turn the screw, and to produce the traverse motion.

Another form of traversing jack is shown at Fig. 2480, side elevation; Fig. 2481, end elevation; and Fig. 2482, section through vertical screw. The lift of this jack is effected by means of a crank or lever, applied to the axis a, which works the bevel-gear $b\,c$, the latter gear being cut on the projecting face of the nut c; the revolution of this nut lifts or lowers the vertical screw, and with it the jaw d; the screw-head, moving freely in a socket of the jaw-head, permits the latter to rise or fall without side movement. The horizontal screw $a\,a$, working into a nut in the foot of the upper screw-frame, effects the horizontal or traversing movement of the jack, the frame of the lower screw serving as a bed or slide for the latter movement. A ratchet-lever may be used to work either of the screws instead of a crank.

The Hydraulic Jack devised by Mr. R. Dudgeon is the simplest and most portable in comparison with the force it is capable of exerting. The ordinary form of base jack is shown in Fig. 2483, and

2483

2484.

Fig. 2484 is a sectional view of a locomotive jack. The machine is from 2 to 8 or more inches in diameter, according to the power desired, with an enlarged head (attached to the inner cylinder B, which is the ram), having a socket for the reception of the lever, by which the piston of the force-pump is worked. The ram, with its head, contains just so much water or other fluid as is required to fill the vacancy in the cylinder caused by the raising of the ram in the act of lifting; and when this is accomplished the water is returned into its original recess D by a valve operated by the lever that works the pump. The force-pump, piston, and valves are contained inside of the ram. The lever L is detached, and may be put on at pleasure. The joints in the head maintain a parallel motion for the force-pump piston, which is the fulcrum of the lever. The ground-lifting attachment is an iron tube screwed into the lower side of the head, and passing down to the bottom of the press outside of the cylinder, on the lower end of which is a claw that supports the weight to be raised. These jacks are light, portable, and of easy application. A jack to raise 4 tons weighs not more than 50 lbs., and one to raise 60 tons not more than 200 lbs. They are all worked by the labor of one man only, which is capable of raising 10 tons through a space of one foot in 1¼ minute, or 60 tons the same distance in 10 minutes.

JACQUARD LOOM. See Looms.

JETTY. A jetty is a dike or pier constructed of wood or stone, or of both combined, and projecting into the sea from the shore, in such a way as to cover the harbor from the action of wind and waves. Jetties are also constructed for the purpose of securing sufficient depth of water at the mouths of rivers obstructed by bars, this result being obtained by contracting the natural channel of the river by two lines of jetties, and thereby increasing the velocity of the current sufficient to keep the channel free from deposits of material brought down by the river.

The Mississippi River Jetties.—One of the most important engineering works of modern times has been the construction of the jetties at the mouth of the Mississippi River, by Captain James B. Eads. The object was to create and permanently maintain a wide and deep channel between the South Pass of the Mississippi and the Gulf of Mexico, 30 ft. in depth and 350 ft. in width. South Pass is one of the three into which the river divides itself about 12 miles above the gulf, Southwest Pass and

Pass à l'Outre being respectively to the right and left of it. South Pass is much the smallest of the three, and across its head there stretched a wide bar having but 14½ ft. of water at average flood-tide. In order to obtain a deep ship-channel to the gulf through South Pass, it was necessary to deepen the bar at the head of the pass. Immediately below the bar the South Pass becomes at once much more narrow and deep, and assumes its normal cross-section. It is from 600 to 700 ft. wide, and from 45 to 55 ft. deep. The general course of the pass is a reversed curve, the reversing point being near Grand Bayou, where a volume was thrown out to the right that was about 23 per cent. of the volume of the pass. By means of a dam constructed at Grand Bayou, this entire volume is thrown into South Pass. The length, from the head of the pass to the land's end at the mouth of the pass, is about 10 miles. Here the water began to spread out to the left over a bar extending for a mile toward the gulf. The western shore of the pass also recedes quickly. At a distance of 4,000 ft. from the eastern land's end, the width of the pass is about 1,700 ft., measured from the bar on the east to the shore on the west. The western shore now receded more rapidly, and at a distance of 2,000 ft. farther out there was no shore on either hand to confine the river water, except a small reef on each side. It therefore rapidly spread out, losing its velocity and consequently its carrying power, thus by deposits of sediment slowly forming shoals and bars. In the central thread of the current the depth was greater, and the velocity was retained by the momentum of the volume in the still deeper channel-way above. This velocity was soon lost by the gradual shoaling, and a bar, having but 7½ ft. of water upon it at average ebb-tide, was formed directly across the pass, connecting with bars still more shoal on either side.

The objects in view in locating the jetties were to maintain between them a width that would insure a permanent depth of 30 ft., and so to direct the outflowing current as to give it the benefit of the strong westerly current that is found in front of the delta of the Mississippi, caused by the prevailing easterly winds. The width determined upon was 1,000 feet.

The guide-piling for the east jetty was the working line for the location. It commences at land's end and skirts the edge of the bar for 9,000 ft., which in a great measure protects the work from the waves of the gulf. Beyond this point the jetty is exposed to the full violence of storms and breakers. The bar beginning at land's end had an upward slope seaward averaging 1 ft. in 400 ft. This ascent was very uniform until the summit was reached, where there was a plateau about 3,000 ft. long. The depth on this plateau did not vary much from 7½ ft. at average ebb-tide. At the sea end of it there was a descent of about 1 ft. in 60 ft. to the deep water of the gulf. The guide-piles at the sea end of the east jetty were placed in 35 ft. of water. The west jetty piling commenced at a point 1,000 ft. west of the east jetty and 4,000 ft. from the land's end, on the east side, measured on the line of the east jetty. Its alignment was parallel to that of the east jetty, and extended to a point nearly opposite to the end of the east jetty. The ultimate limit is in a line due west from the end of the east jetty. This arrangement throws the east jetty seaward of the west about 300 ft., to give a sheltered entrance to vessels. The piles in both jetties were driven as guide-piles only for the willow-work, and did not in any way form a part of the final construction. During the progress of the work they assisted materially by forming a good anchorage and protection for the more important mattress-work laid against them. The west jetty is connected with the shore by a dike of piling and willow-work.

2485.

The willow strips of which the jetties are made were obtained on the delta of an old crevasse in the river called the "Jump." The method of compressing the strips into "mattresses" is shown in Figs. 2485, 2486, and 2487. The ways on which the mattresses were made were simply an inclined plane made of timbers placed at right angles to the banks of the pass, with the lower end in the water and the upper about 6 ft. above it. The inclination of the timbers was about 1 in 10. They

2486.

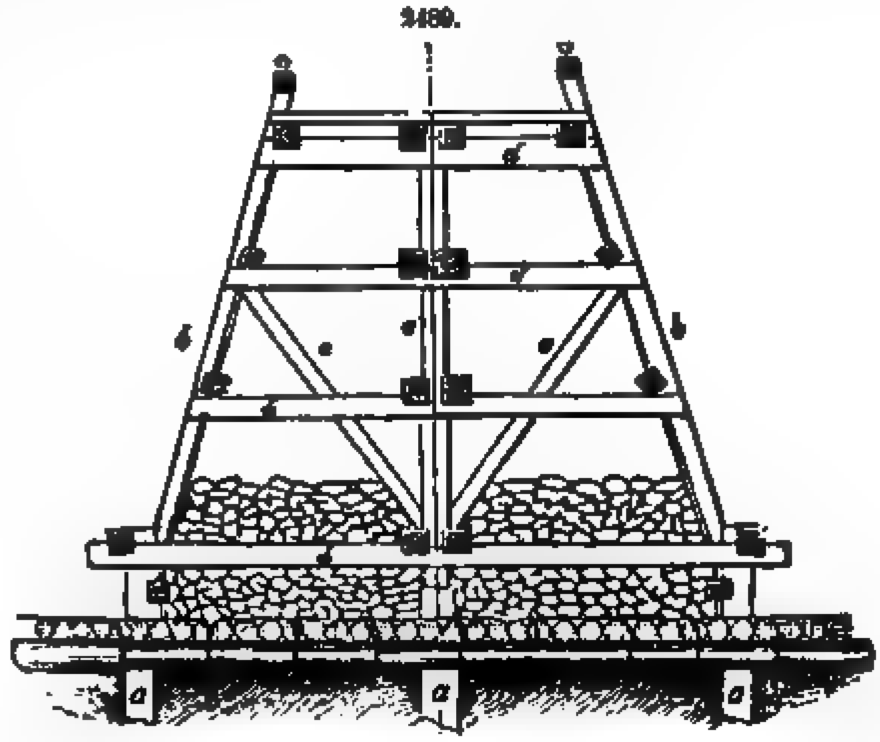
were placed 5 ft. apart, on piles driven to the proper height, and tops cut to the bevel of the incline. On these timbers, and lengthwise of them, was a ribbon of 3-by-3-inch scantling. This was spiked to the timbers, and had its upper surfaces adzed off to the width of half an inch. These ribbons were then well greased, and a floor was nailed to the under side of the timbers to prevent workmen falling through. The material for the frames of the mattresses was piled up just above the ends of the ways. These strips were 2½ by 6 in., and from 25 to 45 ft. long. The mattresses being usually 100 ft. long, the strips were cut to make that length when joined. After being placed upon the ways the joints were fastened by a lap of the same material, about 6 ft. long, and spiked to the strips.

Holes were then bored through these strips 1½ in. in diameter, and at distances of 5 ft. apart; hickory pins, the ends being turned to fit the holes tightly, were driven into them, and oak wedges into the lower ends of the pins. The strips, with the pins standing upright, were then moved down the ways and spaced 4 ft. 6 in. apart. The willows were then carefully placed side by side on the

2487.

strips across the frame. These were laid in layers of 6 in., alternately crosswise and lengthwise, until they reached above the tops of the pins. Strips of about 40 ft. in length, after having been bored to correspond with the upper ends of the pins, were placed across the mattress, pressed down with levers, and secured with wedges. Thus completed, each mattress was pulled off the ways by a tug-boat and towed to its location on the line of the jetties, where it was sunk by weighting it with stones. The cross-section of the finished jetty is shown in Fig. 2488. A mattress 2 ft. thick and from 35 to 50 ft. wide is laid on the bar for a foundation. On this the other courses are laid, of less width but usually the same thickness, each course being sunk and securely held in place by rock. When the slope of the bed between the jetties becomes formed to suit the new cross-section, and when the edge of the foundation mattress drops down to meet this slope, another mattress is laid on the slope and against the edge of the foundation mattress. The whole surface of the mattress exposed is then covered with rock. Dimension stones, laid dry but close together, form the crown of the jetties, and appear above the water. At the sea ends of the jetties are long easy slopes and a covering of heavy stone.

2489.



Effect of the Jetties.—The act of Congress enabling Captain Eads to undertake the construction of the jetties was passed March 3, 1875, and work was begun during the following month of May. Up to March 4, 1876, 1,791,703 cubic yards of the volume of the bar had been removed. In June, 1878, there was a channel 22 ft. deep at average flood tide throughout South Pass and between the jetties to deeper water in the gulf. The least width was 160 ft.

See "Annual Reports upon the Improvement of South Pass of the Mississippi River," by M. R. Brown, Captain of Engineers U. S. A. A report by a commission of army officers to the Secretary of War made in 1879 establishes very fully the complete success of the works, and testifies to the con-

stant improvement in the jettied channel, resulting in its deepening to 28 ft. The Commission also testifies to the fact that, instead of there being a re-formation of the bar in front of the jetties, there has been a deepening of the water in advance of them, and a decided disappearance of bar material over an area of a mile and a quarter square.

Stone and Wooden Jetties.—The cross-section and construction of a stone jetty differ in nothing from those of a breakwater, except that the jetty is usually wider on top, 30 ft. being allowed, as it serves for a wharf in unloading vessels. The head of the jetty is usually made circular, and considerably broader than the other parts, as it in some instances receives a lighthouse or a battery of cannon.

Wooden jetties are formed of an open framework of heavy timber, the sides of which are covered on the interior by a strong sheeting of thick plank. Each rib of the frame consists of two inclined pieces which form the sides, of an upright centre-piece, and of horizontal clamping-pieces, which are notched and bolted in pairs on the inclined and upright pieces. The ribs are connected by larger string-pieces at their points of junction. The foundation on which this framework rests consists usually of 3 rows of large piles driven under the foot of the inclined pieces and the uprights. The rows of piles are firmly connected by cross and longitudinal beams notched and bolted on to them; and they are, moreover, firmly united to the framewo.k in a similar manner.

Fig. 2489 represents a cross-section of a wooden jetty. The foundation of the jetties requires particular care, especially when the channel between them is very narrow. Loose stones thrown around the piles is the ordinary construction. The top of the jetties is covered with a flooring of thick plank, which serves as a wharf. The sides of jetties have been variously inclined; the more usual inclination varies between 3 and 4 perpendicular to 1 base.

Groins.—Constructions termed "groins" are used whenever it becomes necessary to check the effect of the current along the shore, and cause deposits to be formed. These are artificial ridges which rise a few feet only above the surface of the beach, and are built out in a direction either perpendicular to that of the shore, or oblique to it. They are constructed either of clay, which is well rammed and protected on the surface by a facing of fascines or stones, or of layers of fascines, or of one or two rows of short piles driven in juxtaposition; or any other means that the locality may furnish may be resorted to, the object being to interpose an obstacle which, breaking the force of the current, will occasion a deposit near it, and thus gradually cause the shore to gain upon the sea.

JIB. See CRANES AND DERRICKS.
JIG. See CONCENTRATING MACHINERY.
JIG SAW. See SAWS.
JOINER, OR JOINTER. See MOULDING MACHINERY.
JOINERY. See CARPENTRY.
JOINTS. See CARPENTRY.
JOISTS. See CARPENTRY.

JOURNALS are those parts of rotating pieces which are supported by the frame of the machine. They are commonly cylindrical, but sometimes spherical or conical. Some journals run constantly; others support a piece which moves occasionally. In the latter case, the strength of the journal is chiefly to be considered; in the former, durability and freedom from liability to heat are as important as strength. Some journals are subjected to straining forces in the plane of their axis only, which produce bending and shearing stress. Others are subjected to bending and torsion, and are calculated by the rules for combined stress. Lastly, some journals are supported at one end only; others, which may be termed neck-journals, are supported at both ends.

Length of Journals.—Common experience shows that for journals working at high speeds a greater length is necessary than for journals running at low speeds. Journals running at 150 revolutions per minute are often only one diameter long. Fan-shafts, run at 1,500 revolutions per minute, have journals 6 or 8 diameters long. If the journal works occasionally for short periods of time, it is desirable to make it short, because the less the length of the journal, the smaller its diameter may be for a given load, and consequently the less will be the friction. If the journal runs constantly, it requires a larger surface to insure durability and coolness in working. The larger surface is better obtained by increasing the length than by increasing the diameter of the journal. In the former case the friction remains the same; in the latter it is increased. Some increase of diameter is necessary to maintain equal strength, but the diameter should be increased only so much as is necessary for that purpose.

If a journal is strong enough when of length l and diameter d, then if for any reason the length is increased to $l_{\prime}$, the diameter must be $d_{\prime} = d\sqrt[3]{\frac{l_{\prime}}{l}}$ to obtain the same strength as before.

Example.—A journal 3 in. in diameter and 6 in. long has its length increased to 9 in. What should be the diameter?

$$d_{\prime} = 3\sqrt[3]{\frac{9}{6}} = 3 \times 1.1299 = 3.39 \text{ in.}$$

The length of journals, to insure durability and cool working, depends not only on the pressure to which the journal is subjected, but also on the material of the journal and steps; on the kind of motion, whether continuous rotation or oscillation; on the perfection of the lubricating arrangements; and on the accuracy of workmanship. It is not surprising, therefore, that in different cases journals subjected to the same load and running at the same speed should have different lengths.

For railway journals, running at the same speed, the length should be simply proportional to the load. For engines of the same kind, running at the same speed, the crank-pin length should be pro-

portional to the load on the piston. (See CRANK.) For locomotive engines working at the same pressure the crank-pin length should be proportional to the piston area.

The following table shows the theoretical length of journals in inches:

LOAD ON JOURNAL IN LBS.	REVOLUTIONS OF JOURNAL PER MINUTE.					
	50	100	200	300	500	1,000
1,000	.2	.4	.8	1.2	2.0	4.0
1,500	.3	.6	1.2	1.8	3.0	6.0
2,000	.4	.8	1.6	2.4	4.0	8.0
3,000	.6	1.2	2.4	3.6	6.0	12.0
4,000	.8	1.6	3.2	4.8	8.0	16.0
5,000	1.0	2.0	4.0	6.0	10.0	20.0
10,000	2.0	4.0	8.0	12.0	20.0	40.0
15,000	3.0	6.0	12.0	18.0	30.0	...
20,000	4.0	8.0	16.0	24.0	40.0	....
30,000	6.0	12.0	24.0	36.0	....	....
40,000	8.0	16.0	32.0	....	....	....
50,000	10.0	20.0	40.0	....	....	....

The ordinary empirical mode of proportioning the length of journals is to make it proportional to the diameter, and to make the ratio of length to diameter increase with speed. For wrought-iron journals this ratio $\left(\frac{l}{d}\right) = .004\ N + 1$; N representing the number of revolutions per minute. This gives the following table:

$$N = 50 \quad 100 \quad 150 \quad 200 \quad 250 \quad 500 \quad 1{,}000$$

$$\frac{l}{d} = 1.2 \quad 1.4 \quad 1.6 \quad 1.8 \quad 2.0 \quad 3.0 \quad 5.0$$

Cast-iron journals may have $\frac{l}{d} = \frac{9}{10}$, and steel journals may have $\frac{l}{d} = 1\frac{1}{4}$ of the above values.

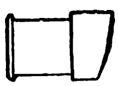
A good theoretical discussion of this subject will be found in "Elements of Machine Design," Unwin, New York, 1877, from which the foregoing is abridged. See also CRANK, FRICTION, and LUBRICANTS.

FORM AND FITTING OF JOURNALS.—In Figs. 2490, 2491, and 2492 are shown the ordinary forms of journal-bearings. Fig. 2493 is a plain journal, such as is employed for the ordinary axles of wheels, or for crank-pins; Fig. 2494 is the class of journal used in cases where it is of importance that the wear of the bearing-box shall not give lost motion or play, as it is technically turned, endwise; and Fig. 2495 is a ball-journal, which together with its box is termed the ball-and-socket bearing or joint. The last is employed in cases where the piece or part carrying the bearing-box requires to have motion in more than one lateral direction. The bearings, boxes, or brasses for these journals are made to have a close working fit to the journals, but the forms of the bases or bedding surfaces of the brasses are governed by considerations as to the strength of the pieces holding them, and the facility for packing them to take up the wear of the brasses and maintain them, so that their boxes shall keep their original positions notwithstanding the wear.

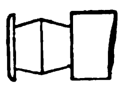
Figs. 2493, 2494, and 2495 are the three forms commonly employed, and below them are respectively the forms of strips or lining-pieces required to be placed beneath them to lift them in their seats when their boxes have worn down.

In Figs. 2493 and 2494, these pieces are thickest at the crowns and thinned on each side; this

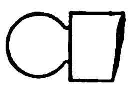
2490.



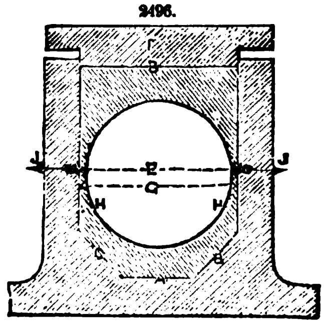
2491.



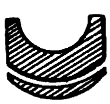
2492.



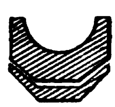
2496.



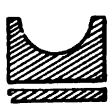
2493.



2494.



2495.



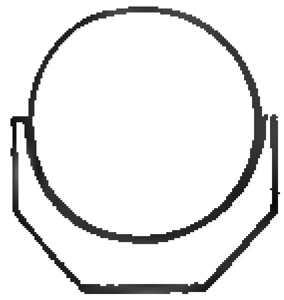
necessitates their being carefully fitted to the boxes and to the brasses; while for Fig. 2495, a plain piece of sheet iron is all that is necessary. The two first, however, leave the pedestal or post the strongest, and are often employed on that account.

The great consideration in fitting a brass to a journal is, that the bearing between the surfaces shall have equal contact, and that the brasses shall properly fit to the box or strap containing them; and so long as this is the case, the oil will not be so readily pressed out from between the surfaces,

and there will be no undue pressure tending to cause any part of the bearing area to wear unsmoothly. From the nature of the duty placed upon bearings, a brass or bearing, however properly fitted at first, alters its form, causing it to bind improperly upon the journal-bearing, and hence to heat. Suppose that Fig. 2496 represents a pillow-block, the brass being properly bedded in the block, and fitted evenly to the journal. The bottom brass beds upon the surfaces A, B, C, and the top brass is held down by the contact of the surface D with the cap F. Now the pressure upon these surfaces A, B, C, and D compresses them, so that after the brasses have been some time in use any marks upon the block or the cap will be plainly impressed on the brasses; and it follows that from this compression those surfaces are stretched or expanded or tend to stretch, and although the form of the surfaces A, B, C is such as to prevent their length from becoming elongated, yet the metal in their neighborhood is expanded, and finds relief in closing the brass across the joint, as denoted by E. This is the theory, and certain it is that the brasses do in time become slack in the block across the diameter denoted by G. Now the brass is the weakest across the diameter G, the disposition of the metal not being such as to give strength in that direction; and as a result the stretching of the metal around A, B, C causes the brasses to bind unduly upon the journal at and near the joint, as denoted by the dotted segments of a circle H. To prevent this, the brasses are, in English practice, filed away at that part of the bore (on each side of the brass-bore) denoted by H; and whenever the brass has worn sufficiently to bring that surface into contact with the journal, the filing is repeated, even though the thrust of the journal is in the direction denoted by the arrows J J. The amount to which this closure occurs depends to a certain extent upon the thickness of the metal of the brass at its joint-face.

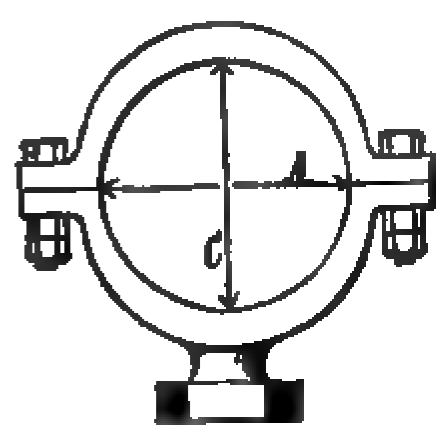
Cases commonly occur in practice where, the joint-faces of brasses having been left well open, as in Fig. 2497, to allow of their closure to take up the wear, and not having been taken out to refit for

2497.

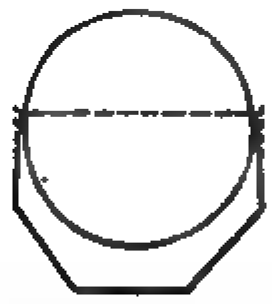


2499.

2500.

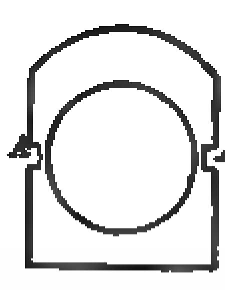


2498.

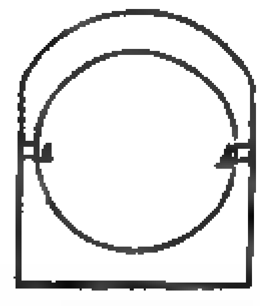


2501.

2502.



2503.



a long period, the brass has worn to admit more than one-half the circumference of the journal, and has closed upon it, as shown in Fig. 2498, its form having altered from the dotted perpendicular lines, causing it to grip the journal so tightly as to require a hammer to drive it off. To avoid this, some bearings are made in four pieces, as shown in Fig. 2499, the two pieces A and B being set up to fit the journal by means of the set-screws C D. The object of this arrangement is to have a bearing upon the journal in a direction to directly resist the thrust of the shaft, that thrust being in the direction denoted respectively by the arrows E and F. In this case the brasses will have contact with the journal all over the area of the bore, which, so far as the amount of area goes, is an advantage; but it is assumed that the curve of the brass is not sufficiently operative to prevent the bore from wearing oval, or in other words, that in the absence of A B the brasses would wear, whereas such is not, in the case of locomotives at least, found to be the case. Furthermore, the pressure and stretching of the metal of the brass at G, H, I, and J will cause the brasses to close upon the journal to some extent, at and toward K K and L L, or, in the attempt to do so, to bind in those places unduly upon the journal, destroying the smoothness that is essential to durability. The setting up of the pieces A B also requires very skillful operation, as it is only by the resistance of the screws that one can estimate how much to set them in, and it is not uncommon to see an engineer after setting them up go occasionally to the bearing, and feel if it is getting warm; if so, he slacks back the screws a trifle, or, if there is a knock or pound, he will set them in a little more. Now, suppose, by being a little too tight, the bearing has heated, the probabilities are that the undue friction has destroyed the smoothness of the bearing, and then the excellence of the same is destroyed, and rapid wear and excessive friction will continue until the surfaces get smooth again, which some-

times is not until they have been fine-filed all over, and even then they will not be so smooth as they become under proper wear.

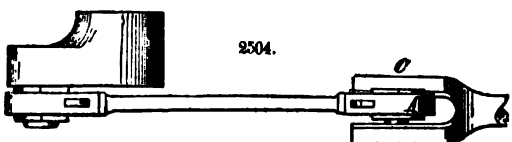
A large proportion of the labor involved in the fitting of bearings to their journals may be saved by skillful manipulation in boring them. It is found in practice that owing to the unequal cooling of brasses in the mould in which they are cast, there exist internal strains in the metal, and that as these strains are locally removed by cutting away the surface of the metal the form of the casting alters. In semicircular pieces the two ends always approach each other from being bored. Thus, the bore of the eccentric strap shown in Fig. 2500, after being turned, would be narrower across *A* than across *C*, each half fitting upon the eccentric as shown in Fig. 2501. To remedy this difficulty, the following methods are adopted. In small brasses—that is to say, those whose bore is 4 in. or less in diameter—the patterns for the two brasses are sometimes made in one piece, as shown in Fig. 2502, being joined together by the narrow piece shown on each side at *A*. The practice then is to fit the brasses to their places, and to bore them out to a diameter larger than that of the journal; then, after boring, to cut them in half at *A A*, and let them sufficiently together; the result of the operation being that, even though the brasses close across the diameter, as shown in Fig. 2500, they will fit down upon the crown, and not bind, as shown in Fig. 2501. The objection to this plan is that the brasses will close across the diameter *C*, in Fig. 2500, after they are bored (that is to say, when they are cut in halves) at *A* in Fig. 2502, to a degree greater than would be the case if they were cast separately; and though, through being bored larger in diameter than the bore of the journal, they may bed well upon the latter, they will have become loose in the strap or box unless care has been taken, in fitting them, to leave them a tighter fit in the strap or boxes than they are intended to be when finished (a precaution that should be taken in all brasses of 8 in. and less in bore.)

Another method is to place between the joint-faces of the brasses or bearing-boxes a piece of sheet metal, as shown at *A* in Fig. 2503, whose thickness it is found should bear the relation to the size of the bore of about $\frac{1}{64}$ inch to 6 in., and to bore the brasses larger than the journal to the amount of the thickness of the metal so inserted. This may be gauged by setting the calipers or gauge to the proper size, and placing a piece of metal of the same thickness as the inserted piece beneath one leg of the calipers when gauging the bore. It is obvious that, were it practicable to make the exact necessary amount of allowance the brasses would require, but little fitting or adjustment would be needed; but it is found in practice that, no matter how true the work may be lined, fitted, and bored, boxes of every description require fitting to their places.

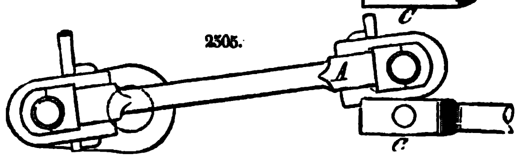
When brasses are held in moving parts, such as levers or connecting-rods, the bearings must be fitted to *lead* true by connecting one end of the rod only, as shown in Figs. 2504 and 2505; and, after adjusting the brasses to a proper fit, the disconnected end *A*, with its brasses in their places in the rod, must be lowered down to the journal; and if the rod at its disconnected end is found to stand on one side of its proper position, it should be moved back and forth under a lateral pressure, placed by hand upon the rod end, and in the direction in which the rod end requires to go, the object of such pressure being to mark plainly the high parts of the journal. This operation, which is called fitting the rod or lever to *lead* true, is indispensable to good workmanship, and, under ordinary duty, to prevent heating; because if a small portion only of the surface of the brass beds to the journal, such comparatively small surface will receive the whole of the friction due to the load of the journal, and will in consequence heat and abrade, cutting a rough surface upon the journal, which must be removed before the journal can be expected to keep cool.

The brasses for fast-running journals should come brass and brass; that is, their faces should touch and lock together by the pressure due to the key or the bolts, as the case may be; so that when, in the fitting, the adjustment is so made as to permit of the key being driven tightly home, there is no danger of the pressure due to the key binding the brasses too tightly upon the journal, and thus causing it to heat. If the position of a box or brass renders it difficult to take it out from

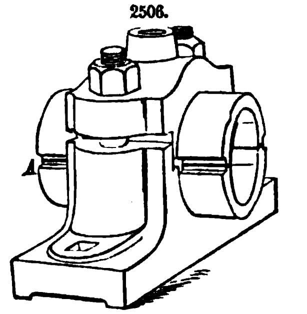
2504.



2505.



2506.



its place, and there is but little wear upon it, the joint of the brasses *may* be left open to permit of adjustment without filing off the faces; but if it is at all convenient to take out the top brass even, the brasses should be made to lock each other by the interposition between their faces of two liners or fitting-strips, as shown in Fig. 2503 at *A A*, which strips may be taken out and filed thinner when it becomes necessary to let the brasses together to take up the wear. To ascertain the thickness such liners require to be, a piece of lead-wire may be placed between the brasses at each of the four corners, and the tightening up of the bolts or key will compress the wire to the requisite thickness. The liners, however, should be made a shade thicker than the wire compresses to, to relieve the journal from any undue pressure from the brasses. If the brasses have a comparatively large

area upon the joint-faces, and are made to come brass and brass, the faces may be cut partly away, as shown in Fig. 2506 at A, thus reducing the area, and rendering the filing or letting together a more easy and expeditious operation. In letting such brasses together, the joint-faces should be made true and square with the flange-faces of the brass, so that locking the brasses together will not spring the latter out of true, and thus cause them to bind unduly upon the journal. In addition to the oil-grooves A A, Fig. 2509, in the crown of the brass, there should be cut in each half brass a groove, such as shown at B B, which groove should terminate close to the end faces of the brasses, thus preventing the oil contained in them from rapidly working out of the journal. J. R. (in part).

2507.

KERF. The slit or notch cut by a saw. (See SAWS.)

KEYS are pieces of metal (usually of steel) employed to secure wheels, pulleys, rolls, etc., to the shafts which drive them. There are four kinds of keys: the sunk key, Fig. 2508; the flat key, Fig. 2509; the hollow key, Fig. 2510; and the feather or spline. The flat key, sunk key, and feather are alike of rectangular form, their differences being in their respective thickness, which is varied to meet the form of keyway which receives them. The flat key beds upon a flat place upon the shaft, the sunk key beds in a recess provided in the shaft, and the feather is fastened permanently in position in the shaft. The hollow key is employed in cases where the wheel or pulley may require moving occasionally on the shaft, and it is undesirable that the latter have any flat place upon it or recess cut in it. The flat key is used where it is necessary to secure the wheel more firmly without weakening the shaft by cutting a keyway in it. The sunk key is that most commonly used; it is employed in all cases where the strain upon the parts is great. The spline is used in cases where the keyway extends along the shaft beyond the pulley or wheel, the feather being fast in the wheel, and its protruding part a working fit in the shaft keyway. This permits the wheel to be moved along the shaft while being driven through the medium of the feather or spline. The following proportions for sunk keys are given by Thomas Box in his treatise on mill-gearing:

The sizes of sunk keys, and the depth to which they should be sunk in the shaft and in the boss of the wheel or rigger, are governed by the diameter of the shaft, but are not in simple proportion to the diameter. The following empirical rules are dictated by experience:

$$\frac{D}{4} + .125 = B; \ \frac{D}{11} + .16 = T; \ \frac{D}{40} + .075 = d; \text{ and } T - d = d';$$

in which D = the diameter of the shaft in inches, B = the breadth of the key in inches, T = the thickness of the key in inches, d = the depth sunk in the shaft measured at the side of the key (see Fig. 2510), and d' = the depth sunk in the boss of the wheel, also measured at the side of the key. The following table is calculated by these rules:

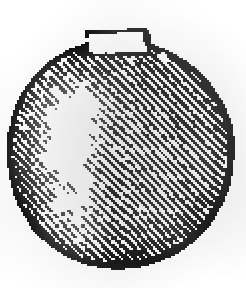
Proportions of Sunk Keys for Wheels and Riggers.

DIAMETER OF SHAFT, INCHES.	1	2	3	4	5	6	7	8	9	10	11	12
Breadth of key.......	3/8	5/8	7/8	1 1/8	1 3/8	1 5/8	1 7/8	2 1/8	2 3/8	2 5/8	2 7/8	3 1/8
Thickness of key. ...	.25	34	.43	.52	.61	.71	.80	.89	.98	1.07	1 16	1.25
Depth sunk in shaft .	.10	.125	.15	.175	20	.225	.25	.275	.30	.325	.35	.375
Depth sunk in wheel.	15	.215	28	.345	41	.485	.55	.615	.68	.745	.81	.875

NOTE.—The depth sunk in the shaft and in the wheel is measured at the side of the key, and not at its centre.

The breadth of the key is equal from end to end, but the thickness must be regulated to give a uniform taper for the purpose of fitting tightly in its place. The amount of taper should be about

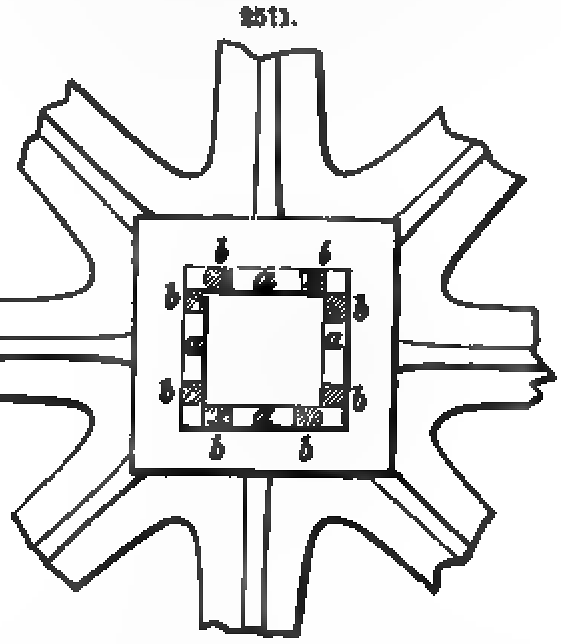
2508.



2509.

2510.

2511.



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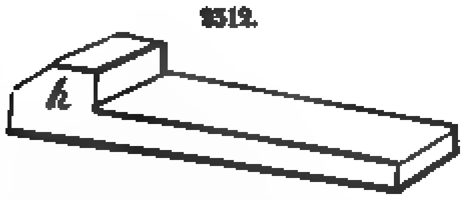
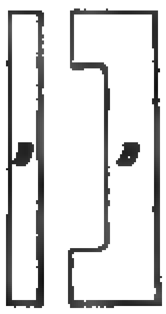


one-eighth inch to a foot in length, and the same must be given to the key-seat in the boss of the wheel, and not to the key-bed in the shaft.

Fig. 2511 illustrates the method of keying a wheel to a square shaft. It is used for shafts that

are not planed or otherwise made true. The wheel is hung upon the shaft, and four temporary keys, having heads as shown in Fig. 2512 at h, with which to withdraw them from the wheel, are inserted in the spaces a, a, a, a, Fig. 2511. (It may be mentioned here that similar heads are generally forged upon keys to facilitate their withdrawal while fitting them to their seats, the head being cut off after the key is finally driven home.) These sustain the wheel while the permanent keys b, eight in number, are fitted, the wheel being rotated and tested for truth from a fixed point, the fitting of the keys serving to true the wheel.

2513.



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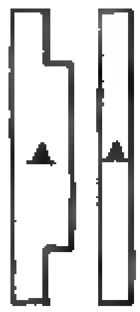


Reverse keys are simple pieces of steel, so shaped as to reverse the draft of a keyway, and are made male and female, as shown in Fig. 2513, A representing the male and B the female. The manner of using them is to insert them into the keyway, as shown in Fig. 2514, in which A represents a taper rod end, B the socket into which A is fitted or keyed, C the male and D the female reverse key, and E an ordinary key. It will be found, on examination, that the insertion of C and D has exactly reversed the position of the draft of the keyway, so that the pressure due to driving in the key will be brought to bear upon the rod on the side on which the pressure was previously on the socket, and on the socket on the side on which the pressure was on the rod; so that driving in the key will key the socket out of instead of into its place. J. R. (in part).

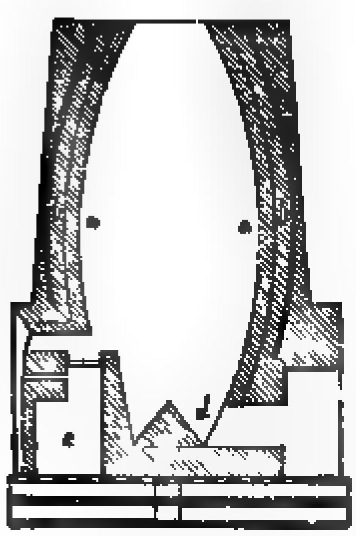
KIBBLES. See MINE APPLIANCES.

KILN. A structure, usually of considerable size, which may be heated for the purpose of roasting, burning, hardening, annealing, or drying anything; as a kiln for burning lime. In contradistinction to the term "kiln," an oven is defined as a place arched over with brick- or stone-work for baking, heating, or drying.

Lime-Kilns.—Many different forms of kiln are used in lime-burning. Fig. 2515 is a section, and Fig. 2516 a plan of a perpetual kiln in use in Prussia, in which one part of wood and four parts of peat are used. $d\ d\ d\ d\ d$ are openings at bottom for drawing the lime as it is burnt; $c\ c\ c\ c\ c$, fire-furnace for the fuel, whose mode of connection with the cavity where the limestone is placed may be seen at c in the vertical section, which also shows at d the manner in which the lime may be

2517.

2515.



2516.

drawn. At $a\ a$ is shown a lining of fire-brick, back of which is a cavity $b\ b$ filled with cinders, which act as a non-conductor of heat. The outside is built of rough stone. It produces about 250 bushels of lime daily.

Fig. 2517 is a vertical section of a plain perpetual kiln. It is 25 ft. high, and built of alternate layers of fire-brick and stone. It is four-sided, consisting of a single chimney 4 ft. square on the inside and 8 ft. on the outside, making the walls 2 ft. thick. To the height of 7 ft. from the bottom it is 12 ft. in one direction, for the purpose of making room for the furnaces $d\ d$, in which wood only is burnt, and which are 2 ft. high and 20 in. wide. For the passage of the heat into the limestone in the chimney the bricks are laid up like a grate. $a\ a$ are ash-pits beneath the fires, b an opening for clearing the lime from the bottom of the chimney, being about 18 in. square. The kiln consumes from 2 to 2¼ cords of wood daily, and produces 75 bushels of lime, which is drawn out at intervals of 8 hours

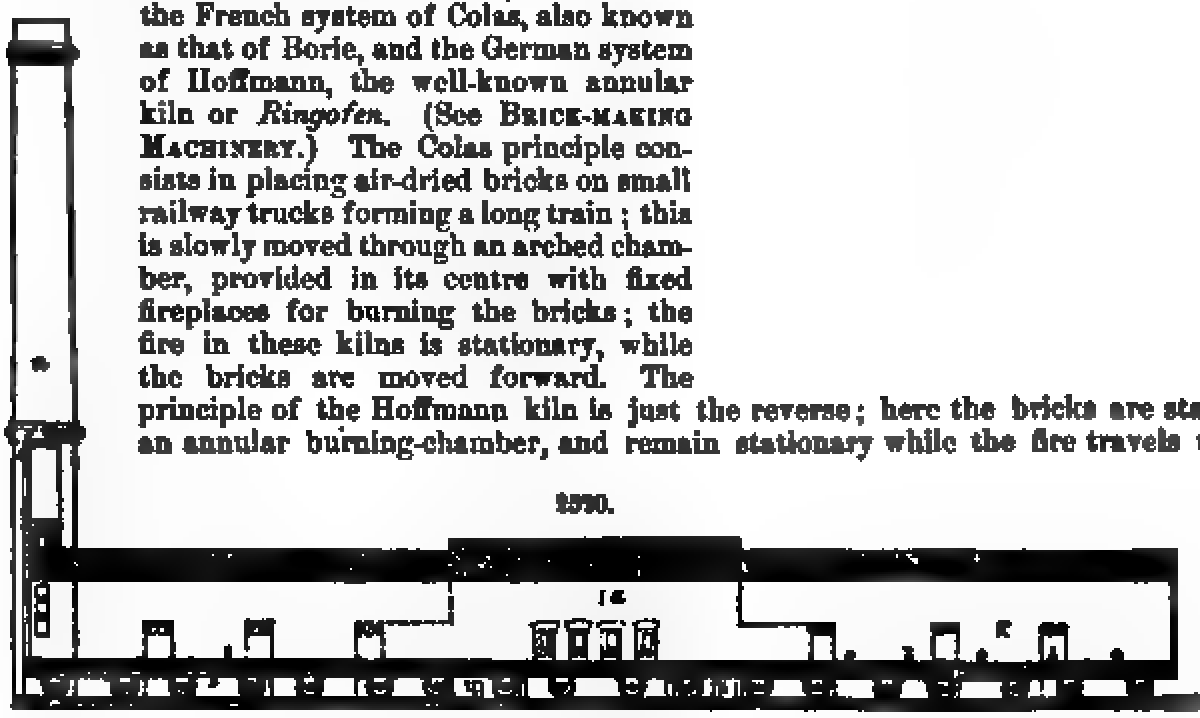
Batchelor's Kiln, Figs. 2518 and 2519, is usually circular in plan, and has a domed roof. The furnaces are constructed in the wall. Inside the kiln, and opposite each furnace, are built short walls forming a casing or pocket round the end of each fireplace, which directs the heat upward toward the upper part of the articles stacked in the kiln. In the floor of the latter there is an opening leading to the main flue D, which conducts the products of combustion to the chimneys. Fig. 2519 shows the arrangement for working a series of these kilns in rotation, so as to utilize the waste heat passing from the kiln, in active operation for the purpose of drying green or unburnt articles stacked

in another kiln, in order to prepare them for final burning. Numbers 1 to 5 represent a series of the above-described kilns grouped around a central chimney L. Main flues D D lead from the centre of each kiln to the chimney-shaft, dampers M M being fitted to each flue to open or close communication between the kilns and chimney, as may be desired.

2518. 2519.

Two systems of continuous kilns for burning bricks, tiles, etc., have come into practical use: the French system of Colas, also known as that of Borie, and the German system of Hoffmann, the well-known annular kiln or *Ringofen*. (See BRICK-MAKING MACHINERY.) The Colas principle consists in placing air-dried bricks on small railway trucks forming a long train; this is slowly moved through an arched chamber, provided in its centre with fixed fireplaces for burning the bricks; the fire in these kilns is stationary, while the bricks are moved forward. The principle of the Hoffmann kiln is just the reverse; here the bricks are stacked in an annular burning-chamber, and remain stationary while the fire travels through them, leaving burnt bricks in the rear, and advancing into and among the green bricks. In this manner the process of burning is continued until the extreme end of the kiln is reached.

2520.



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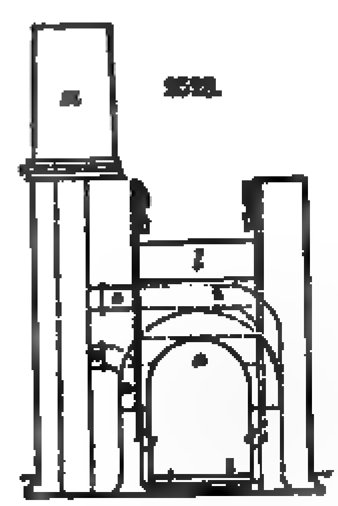


2523.

Foster's Brick-Kiln, represented in Figs. 2520, 2521, and 2522, is constructed according to Colas's principle. The kiln consists of one long parallel chamber a, into which the bricks are passed on

iron wagons having fire-clay tops e; these wagons are constructed to fit the sides of the kiln as at $d\ e$, so as to be as air-tight as practicable up each side. When in operation, the burning part occupies by preference the centre of the kiln, the fires being stationary in the sides of the kiln at f, as shown in Figs. 2521 and 2522, fuel being fed in from the top. A progressive motion is given as required to the wagons containing the bricks, from some suitable motive power. The chamber may

2524. 2526.

2525.

be of any required length to contain a convenient number of loaded wagons at one time. As the bricks on each wagon are burnt sufficiently, the latter is pushed or pulled forward, and another wagon containing unburnt forms takes its place at the burning part of the kiln. As each wagon is admitted at one end of the kiln, another containing burnt forms is simultaneously passed out at the other. Economy in fuel is obtained by placing the fires in one part only of the kiln, which is kept at an intense heat, instead of distributing them as usual. The cool air on its way to the fire passes into the kiln through the outlet for wagons, where it is heated by the burnt bricks, which are themselves gradually cooled. The inlet end for unburnt forms acts as the flue for the heated gases, from whence these pass to the chimney m by flues n. By this arrangement the unburnt forms are gradually heated before being submitted to the intense heat of the firing part of the kiln. When the wagons are drawn from the kiln they may be taken to any convenient place for unloading. Fig. 2520 is a longitudinal elevation, Fig. 2521 a sectional plan on the level of

the furnaces, Fig. 2522 a transverse sectional view on an enlarged scale through Fig. 2520, and Fig. 2523 an end elevation, showing the balanced lifting door *l*. It is claimed that a great saving of labor is effected by the kiln, and that almost all the heat is utilized by the arrangement adopted of heating the air for combustion by the cooling burned bricks, and by passing the heated gases through the mass of unburned bricks. Bricks may be sent into it with less preparation than for the ordinary kiln, and labor is thus still further economized. The bricks after leaving the brick-

2528.

2527.

making machine are only once touched by hand until loaded into vehicles for consumers, and burning is effected, it is said, at a cost of about 6 cents per thousand.

The Dueberg Kiln, represented in Fig. 2524, is claimed to combine the advantages of both the above-mentioned systems. It is an annular kiln with a movable floor which consists of a series of sections or platforms. These platforms are supported by wheels and axles, which run on a railway track extending all along the floor of the burning chamber; the platforms, therefore, are railway

2529.

2530.

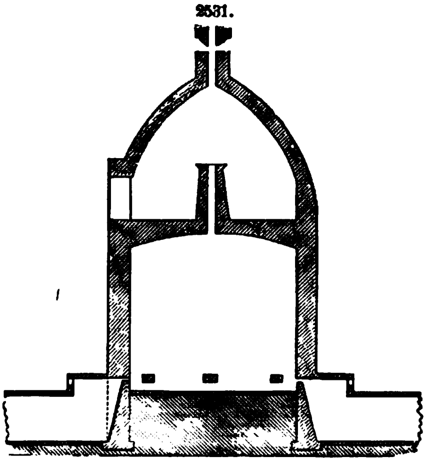
trucks, similar to those used in the kilns of Colas and Borie, but larger than these. The principal difference, and at the same time the principal advantage offered by Dueberg's kiln, compared with those of Colas and Borie, is that the platform trucks are not moved during the burning of the bricks. On the contrary, they are at rest during the entire process of burning, while the fire is advancing through the bricks, in the same manner as it does in the Hoffmann kiln. The fuel is dropped into and among the bricks to be burnt from above, through small holes in the arch of the burning-chamber. The trucks, after being loaded with green bricks, are run into the kiln one by one, each

close up against the preceding one; the back of each truck is coated with clay before the next truck is pushed in, and thus the joint is made air-tight. The two sides of the platforms parallel to the wall of the burning-chamber are made air-tight by filling the joints between the platforms and the kiln-walls with sand, after a truck loaded with green bricks has been run into the kiln, close up against the platform of the preceding truck.

Müller's Kiln, Fig. 2525, consists of a number of chambers separated from each other by perforated sides and bottoms, and disposed across the path of the flame. Through these chambers the articles to be burned or baked are passed along by pistons worked by mechanical means, so as to be gradually brought toward and into the hottest part of the chambers. They are then carried to the cooler portion of the compartments. A small portion only of the surface of the articles is thus exposed to the action of the flame, and the process is progressive and continuous. The chambers are heated by gas from a suitable furnace. Fig. 2525 is a transverse section of this kiln. The articles to be baked are placed in small carriers of refractory clay, and as they move onward are subjected to the intense heat of the flames which enter at *a a*. The flames pass to the upper flue *c*, and their egress is regulated by dampers *d*. The passages through which the articles travel are arranged vertically one above the other, so that each perpendicular row becomes a kiln, the flame of which is regulated at will at both its points of admission and of outlet.

Fig. 2526 represents an improved system of malt-kiln devised by Messrs. Noback & Fretze of Prague, and said to produce great economy in labor and firing. The grain is placed in a horizontally rolling hopper, with a self-acting cover to prevent either egress of heated or ingress of cold air during the time of loading, and falls upon an iron floor consisting of a series of plates working like a Venetian blind on a centre-pin in each. As soon as the grain on the upper floor is ready for turning, the plates of the floor are turned into a vertical position by means of suitable handles, allowing the grain to fall to floor No. 2, while No. 1 is again reversed and filled from the hopper, which in being pushed back spreads the grain evenly over the floor. This process is repeated indefinitely. The necessity for a man to enter the kiln to turn the malt is here obviated by a simple mechanical contrivance. A saving of space is also effected.

2531.



Pottery and Porcelain Kilns.—The kilns for common stoneware vary in form. In England they often have much the shape of an ordinary reverberatory furnace, as shown in Fig. 2527, where *r* is the grate, *a* the ash-pit, *c* the baking-chamber, and *d* the chimney. A vertical form, such as that for earthenware shown farther on, is generally used in the United States. The articles are placed in cells formed of baked slabs, as represented in Fig. 2528. The hot air from the furnace, passing through these open cells, raises the clay to the proper temperature. The firing may continue from 24 to 48 hours, depending upon the size of the pieces, the fusibility of the clay, and the extent of vitrification which may be desired. Fig. 2529 represents the form of kiln used in baking earthenware. A section of this is shown in Fig. 2530.

Fig. 2531 represents a porcelain kiln. The first firing of the material, at a much lower heat than that needed for stone- or earthenware, is conducted in the upper story. After the soft biscuit is glazed, it is fired and converted into finished porcelain in the lower story.

KINEMATICS, OR KINETICS. See DYNAMICS.

KING-BOLT. See WAGON-BUILDING.

KNEADER. See BREAD AND BISCUIT MACHINERY.

KNITTING MACHINERY. Knitting consists in making a fabric by enchaining a single thread. In describing the machines used for this purpose we shall consider—I. Hand machines, and II. Power machines; subdividing these according to peculiarities of form and construction.

Knitting-Machine Needles.—The essential feature of a knitting-machine needle is, that it shall catch and draw the yarn to form the loop, and shall cast it off by allowing it to slip over at another part of the action. The devices for this purpose are flexible beards and loops.

Formerly the only spring-beard needles used were made of hard-drawn iron and brass wire. Needles of this description were used in this country as late as 1848. Those in present use are made from round steel wire, and as the value of the needle depends almost wholly upon the tenaciousness and flexibility of the beard, the manufacturers are content to pay well for a wire containing the desired qualities. Though the justly celebrated "Stubs steel" is excellent for many purposes, it will not do for this department, being too hard, while for needles the steel should be uniform in its temper and very soft; indeed, so pliable is this wire that but for the color one might easily imagine it to be copper. The wire reaches the needle manufacturer in coils, without a speck of rust on its silver-like surface. First comes the process of testing the temper. For this purpose a small piece is cut from each end of each coil and subjected to a test peculiar to the manufacturer. If this proves it faulty in any particular, the coil is laid aside to be used for some inferior purpose. If, however, it proves all right, the whole coil is unwound and straightened by passing it between rollers. It is then cut up into short lengths, generally each length right for two needles. Each end of each piece is now reduced in a milling machine which will mill from 12 to 50 ends at a time (the number milled

depends in a measure on the gauge). The eye is now punched, not sawed, as some suppose. The former plan is preferred, as it leaves the needle much stronger by reason of its condensing the stock instead of cutting it away. They are now reduced to a gauge at the point, head, and eye. This is done with a smooth file. The extra stock caused by the forming of the eye is now also filed off. Next they are polished on an emery-wheel. They are now ready for the machine which turns over the beard and shapes the same. Up to this time each small length of wire has a needle formed at each end. They are now cut in two and carried to another machine which makes several flat places on the shank, which insure its being held firmly in the metal when leaded. Now comes the hardening and tempering process, which in importance ranks next to the quality of steel. They are next dried in sawdust, and subjected to repeated processes of polishing. Then each needle is separately inspected and pliered, after which they are weighed out into parcels of 100 each, and these parcels counted and packed in boxes, each box containing 1,000, in which shape they are usually sold. For length and shape they are generally made to order, and to suit the various kinds of knitting machines. They will vary in length from 1¼ in. to 3 in. The size of wire and cost of finished needles is about as follows, size according to the English wire gauge:

Knitting Gauge.	Wire Gauge.	Cost.	Knitting Gauge.	Wire Gauge.	Cost.
8	16½	$7 00	20	21........	$4 75
10	17	6 93	22	22...	5 75
12	18	5 50	24	22½.....	
14	18½ to 19		30	23......	6 00
16	19½......	4 75	36	24.	
18	20½.....		40	25......	

The life labor of a common gauge needle on a shirt-knitting cylinder is about 18 shirts.

Hosiery Yarn is designated by so many grains, which is determined by the weight in grains of 6 yards of yarn as reeled from the jack bobbin; that is, if 6 yards weigh 10¼ grains, it is called 10¼-grain yarn. In order to more nearly average the weight, 24 yards are for instance reeled off, and the weight in grains and fractions of grains is divided by 4. It is also a good plan to reel the yarn from several bobbins at once to facilitate matters, and a reel just one yard in circumference is most convenient. In one pound avoirdupois there are 7,000 grains troy or apothecaries' measure. In one run there are 1,600 yards.

I. Hand-Knitting Machines.—These may be divided into—1, those in which the needles are placed in a straight row; 2, those in which the needles are circularly disposed; 3, those using but a single needle.

1. *Needles placed in a straight row.*—As an example of this type of machine Lamb's apparatus is presented in Fig. 2532. In this a tubular web is produced by the operation of two straight parallel rows of needles, widening and narrowing being accomplished by increasing or diminishing the number of needles in action. The frame is attached by thumb-screws to the edge of a table, and has its two upper sides inclined toward each other, their upper edges being separated far enough to allow the fabric produced to pass down between them. Supported by the needle-bed is a carriage reciprocated by a crank. The needles employed are self-knitting, being constructed in such a manner that when fed with yarn and carried an inch forward and back, they form the loops by their own action. The lower ends of the needles have an upright shank, extending above the face of the needle-bed, and are operated by cams that are attached underneath the centre of the carriage in such a manner as to move the needles forward and back. There are two sets of these cams, one for each row of needles. *B* is a representation of one of the sets of cams, which consists of the plate *a*, the two wing-cams *c c*, and the V-shaped cam *b*, which is held in place by the screws that pass through the washer *d* in the diagonal slot of the plate *a*. As the carriage to which these cams are attached is drawn back and forth over the needle-bed by the crank, the needles are carried up on one side of the V-shaped cam in the groove or space between that and the wing-cams, the yarn-guide at the same time delivering the yarn into the hooks of the needles, which are then drawn down by the wing-cam on the other side of the V-cam, thus forming the loops. By the adjustment of the cam-stops, either or both of the cams may be left open or closed at the same time, so as to operate the two rows of needles separately, alternately, or together, thus forming three entirely distinct webs—tubular web, plain flat web, and ribbed flat web.

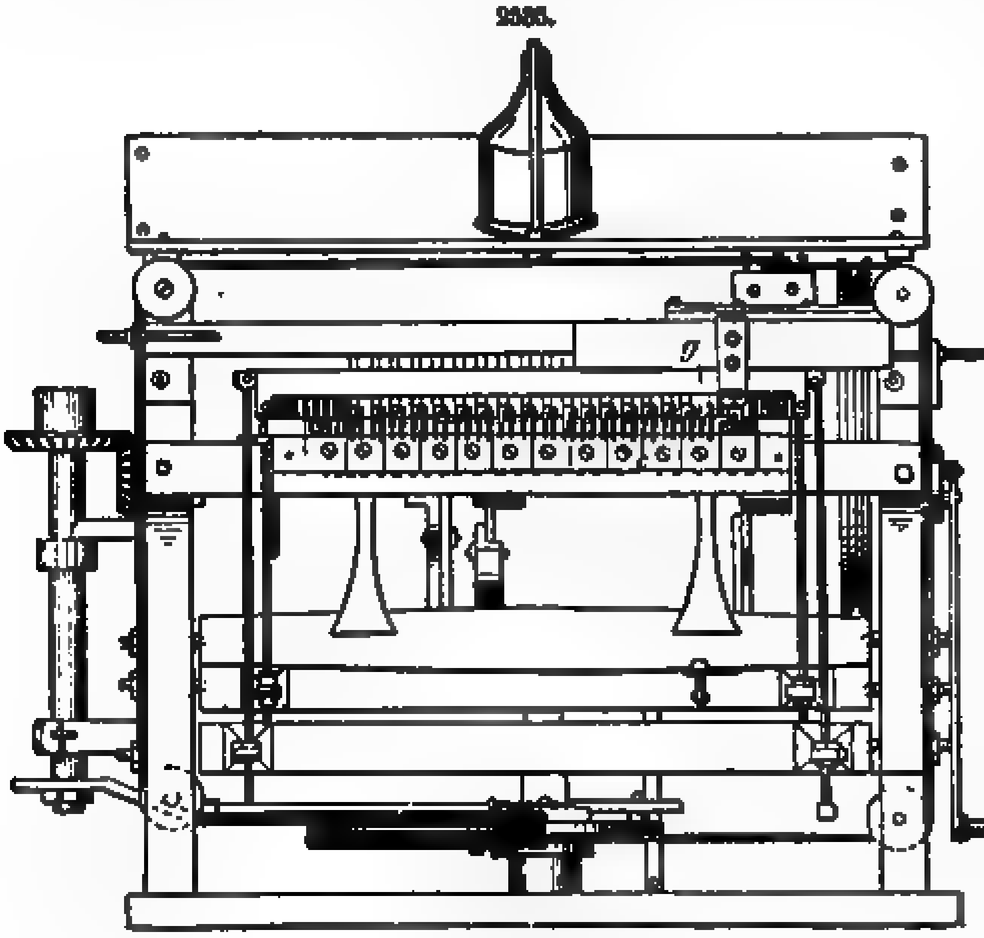
2532.

2. *Needles placed in a circle.*—Fig. 2533 represents the Bickford knitting machine. Fig. 2534 exhibits the arrangement of needles, from which the operation will be best understood. Four of the needles are here shown. The needle complete is represented at 1; a portion of the lower part of the others is broken away. The needle consists of a body, an angular bent portion, a foot, a hook, and a latch. The last is pivoted to the body of the needle, and works partly in a slot formed in the body. The latch has moreover a spoon-shaped end, which when the latch is closed, as shown in needle No. 2, meets and partly shuts over the point of the hook, so that the loop formed on the needle easily slips off when the latter makes its downward movement. Let the reader suppose one line of stitches already formed on these needles, as shown in the engraving, and the thread or yarn to be knit so held that the needle marked 1 will hook over it when the latter descends. The thread will be drawn down by the needle until the latch meets the loop previously formed. This loop, sliding along the body of the needle, lifts the latch and closes it into the position shown in No. 2. The loop then slides off the needle as it continues to descend, and the thread, being drawn down through the former loop, forms a new loop, through which the needle will pass in rising, as shown in No. 4, opening the latch and leaving the hook free to engage the yarn when the latter is brought under it again, and so on. It is obvious that if we supply mechanism that will bring the yarn under the hook at the proper moment, and move the needles up and down successively, and also provide a device for supporting each row of loops till the next row is formed, we shall have a machine that will knit a straight tube. The cams *m m* are screwed on the inside of the cylinder of the machine, which revolves. As these cams are carried around by the revolving cylinder, the angular bent part or foot of the needle passes through the curved space between the cams, and as the needles are held from moving sidewise by being placed in grooves formed in the needle-cylinder, they are forced up and down as desired. Each row of loops is also sustained until the next is formed by means of the needles themselves, as the needle-cylinder prevents their bending inward, and keeps them in a vertical position. The cam-cylinder is moved by a bevel-gear connected to a driving-crank, and when moved continuously in one direction knits a circular web, which may be narrowed as desired by removing needles and placing their loops on adjacent needles.

2533.

2534.

2535.



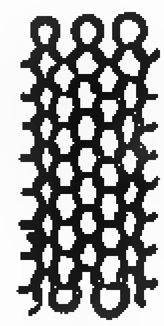
3. *Single-Needle Machines.*—The Hinkley machine is an example of this type. The driving-wheel drives a friction-pulley, and by it a grooved cam-disk by which a comb is operated (by means of a rack) backward and forward before the needle. The needle-bar, receiving its motion from the crank-pin in its slotted arm, advances with each revolution of the disk, and the needle, passing through the stitch immediately in front, under the tooth of the comb, removes that loop from its tooth; the revolution of the cam-slot brings the looper-hook forward in

season to take up a new loop from the eye of the needle, and on its backward movement deposits it on the tooth which held its predecessor. The comb then traverses one tooth for the repetition of the stitch-forming.

II. Power Machines.—Fig. 2535 is an ordinary straight machine for producing a plain flat strip of fabric. The meshes being in their extreme forward position, and the last-formed row of stitches being near their rear ends, the guide g moves along the front of the machine, laying the yarn on the

2536. 2537.

B



stems of the needles. The sinkers e are at the same time depressed, one after another, by the cam or slur above them, and in turn depress the yarn into loops between the needles. The latter are then drawn slightly backward, so that the yarn may pass under their beards. The presser-bar then descends upon and closes the beards, which then enter the old loops of the fabric, and the sinkers are raised in a body by the lifting-bar in their rear, shown in the sectional view. The needles receding to their extreme backward position, the old loops are thrown over their heads by being drawn against the plates $f f$, Fig. 2536. As the needles move forward the sinkers are all depressed in a body in front of the fabric by the bar in front of the sinkers, to keep the loops back on the needle-stems; the needles then move entirely forward and the looping operations are repeated.

The general arrangement of a machine of the ordinary circular kind is given in Fig. 2537. The needles are bearded and fixed around the periphery of a rotating cylinder. The yarn, delivered through the eye in the end of the guide a, is pushed by the notched wings on the loop-wheel b up under the beards of the needles. The wings of the sinker-wheel c then press the yarn in between the needles, to insure that there shall be a sufficient quantity to form the proper-sized loops. The needle-beards are then pressed in, so that their points enter a depression in the stems, by the presser-wheel d, the yarn being thus inclosed between the beard and the stem, the old loops being at the same time raised by the landing-wheel e, a short distance above and outside the points of the beards. The stripping or knocking-over wheel f then throws the old loop entirely over the tops of the needles, and the fabric with the newly formed row of loops is pressed down to the lower ends of the needles by the curved cloth-presser g.

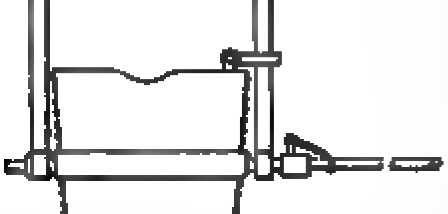
The Tompkins Upright Rotary Knitting Machine, manufactured by the Messrs. Tompkins of Troy, N. Y., is represented in Fig. 2538. The complete apparatus has two cylinders or heads. Each head generally knits four threads at once, and each thread, or the machinery necessary to knit it, is called a feed. One girl can attend to six cylinders. The needles used are the spring-beard, and they are placed in a mould in pairs, and leaded by having a composition consisting of equal parts of lead and tin poured around them. The gauge is determined by measuring the needles and counting the leads when set in the cylinder. For instance, 14-gauge has 14 leads or 28 needles, 3 in. in length, measured on the circumference. In regard to the proper speed of the needles for the different-sized cylinders, needles, and yarn, some believe a quick speed to be best, and others consider it policy to use more machinery and run it more slowly.

As regards the capabilities of the machine, the manufacturers state that a single-cylinder apparatus of 22 in. diameter, 20-gauge, 4 feeds, knitting common hosiery, yarn cotton and wool mixed, running 45 revolutions, has 920 needles, thus making 165,000 stitches per minute. A 16-inch cylinder, 20-gauge, 4 feeds, cotton yarn, has run 79 revolutions, and made 212,532 stitches per minute; and the same cylinder has been run as high as 85 revolutions on the same yarn, at which speed it made 228,-480 stitches per minute. Usually an 18-inch cylinder, 15-gauge, is run 45 revolutions; and a table of two heads which turns off 160 lbs. of knit cloth per day of 11 hours, averaging 15 dozen goods exclusive of waste, is considered as doing fairly.

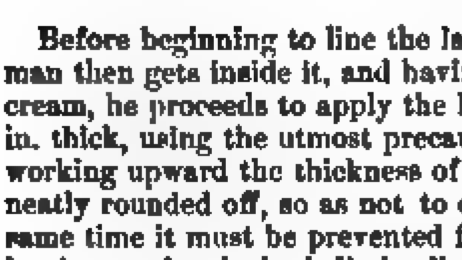
Cone-Winders are used in connection with knitting machinery, for rewinding the yarn as it comes from the spinning-jack bobbin or cop. The Tompkins cone-winder, Fig. 2539, is capable of winding the yarn from one 250-spindle jack. The bobbin runs in contact with the cone, directly in front of and below it, and is so held by a nicely-weighted lever bearing against the rear end of its spindle. The thread or yarn, as it unwinds from the cop on its way to the winder-bobbin, receives first an adjustable tension which insures a firm body to the bobbin, and also causes any slack-twisted spot in the yarn to part and be mended here before it can do harm; from the tension it passes through a variable gauge or stripper, which cleans off cotton seeds, snarls, or unequal sizes in the yarn. The stripper is secured to the frame low down, in such a position that advantage is taken of the back-and-forth motion of the thread. There is also a wire fastened in such a manner as to cause extra friction on the thread while forming the noose. From this it runs on to the bobbin, which it reaches by first passing over the traverse arm, which has a quick motion, thus crossing and recrossing the thread, making it hardly possible for two circles or a double thread to run off while knitting. Each bobbin holds about 22 cops, or 1.8 lb. of yarn, 14-gauge, which will supply a knitting feed for about one hour. The speed of the drum-shaft is about 340 revolutions per minute.

LADLES are used in foundries for receiving molten metal as it flows from the furnace, and transporting it to the moulds. Figs. 2540 and 2541 are a plan and elevation of a common form of heavy ladle, generally made of boiler-plate, which should be strong and thick, with double-riveted butt-joints, heads of the rivets inside, and a strong angle-iron ring round the bottom. The shape is cylindrical, with the bottom slightly concave inside, and it is usual to roughen the internal surface with a view of giving a better hold for the loam coating. The plates of the ladle are frequently perforated with a number of holes, about half an inch in diameter, a precaution which is especially useful in large ladles, as allowing an egress for the gases which are generated in the lining when the molten iron is run into them from the cupola. The tendency of these gases, if pent up, is to split off some of the lining from the ladle; the liquid cast iron then coming in contact with the plates heats them to a dangerously high temperature, when the least evil to be anticipated is the bulging of the sides from their correct form, thus interfering with the action of the gearing employed for tilting them when pouring into the mould. The body is surrounded by a strong iron ring, from which two trunnions project; over these the holes in the frame fit, the upper bar of the frame having a stout eye for slipping it on to the hook of the crane-chain. A loose swinging fork is arranged on one of the upper edges of the ladle, and by throwing this into or out of gear with the side of the frame next to it, the ladle is kept vertical or swung over at pleasure. A handle fits on to the prolongation of one of the trunnions, and is a rough means of regulating the quantity and rate at which the metal is poured.

2540.



2541.



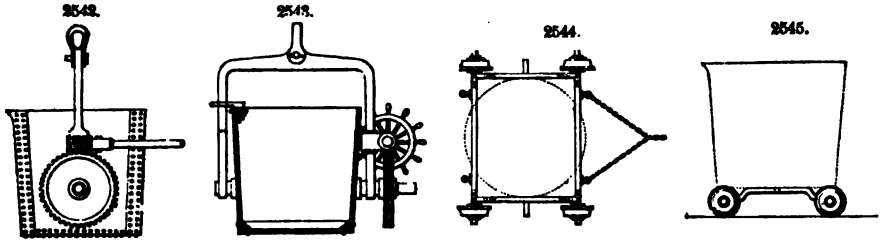
Before beginning to line the ladle, it is advisable that it should be slightly heated; the furnace-man then gets inside it, and having coated the interior with a wash of clay of about the consistence of cream, he proceeds to apply the loam to the bottom of the ladle in a uniform coating from 1 to $1\frac{1}{2}$ in. thick, using the utmost precaution to force it into close contact with the plates at all points. In working upward the thickness of the lining is slightly reduced, and the covering of the lips must be neatly rounded off, so as not to oppose any uneven surface to the flow of the metal, while at the same time it must be prevented from coming into contact with the iron of the ladle. When the lining is completed, the ladle is allowed to stand until the loam has dried sufficiently to allow of the ladle being turned upside down without disturbing the lining. A fire is then lit beneath the ladle, so

as to completely dry the lining. The ladle must be slightly tilted on one side, to allow the damp air and smoke to escape. The nature of the fire thus applied somewhat depends upon the convenience of the works, but one of the simplest and readiest modes is to place a pile of ignited coke on a piece of old sheet iron, and run it under the ladle. If any cracks are observed in the lining during the process of drying, they must be filled up with moist loam; and when the whole is perfectly dry and uniformly covered, without cracks or flaws, a coating of thick black wash is applied. When about to toss the metal into a ladle, an old piece of plate should be placed in a sloping position, resting against one side of the bottom, so as to prevent the first force of the current of metal from coming into contact with the lining; this plate must be removed with the tongs when there is metal enough in the ladle to receive the flow of the falling metal. The "breaking of the iron" in the ladle is useful as an indication to the founder of its temperature.

A convenient mode of tipping the ladle is obtained by the arrangement in Figs. 2542 and 2543. The strong wrought-iron cross-head is brought down on each side to nearly the bottom of the ladle, where it is bent round extra-strong lugs or trunnions. Upon one of these trunnions is keyed a cast-iron worm-wheel, which is geared into by an endless cast-iron screw, carried by bearings attached to the side bar. The end of the axis of this screw is square, so as to fit the socket of the long shaft, which is caused to rotate by means of a capstan-wheel, fixed at such a distance from the ladle that the man working it shall not be inconvenienced by the heat of the metal in the ladle. This arrangement enables the ladle to be quickly and safely tilted to any desired angle. In order to insure its steadiness when in an upright position, the usual forked catch with a hinge is riveted on one side of the ladle; the fork embraces the vertical arm of the cross-head, thus preventing any movement out of the perpendicular until the catch is disengaged.

For conveying the filled ladle from the cupola to the mould, an overhead traveler can be used (see CRANES AND DERRICKS), or a small but strong wrought-iron truck, running on light rails, may be employed, so arranged as to run the ladle within command of the sweep of the crane used in pouring. The rails should be laid a few inches below the usual floor level of the shop, and when not in use be

2542. 2543. 2544. 2545.



covered in with sand to protect them from any liquid metal that may be spilt. The wrought-iron carriage for the ladle is usually constructed as shown in Figs. 2544 and 2545, by mounting four small cast-iron flanged wheels on strong wrought-iron axles. Two cross-bars are riveted to the axles, a little farther apart than the diameter of the ladle; these are slightly cranked upward, so as to embrace the ladle between them, which rests on the axles. Two strong hooks are fixed on each axle, to which the chain is attached by which the ladle is drawn along the rails. Projecting horizontally a few inches from each side bar is a square stud, which is used as a means of arresting the motion of the truck; this is effected quickly, but without any jolt or jar, by a workman who follows the truck. He is provided with a long iron bar, which he slips under the stud, and rests upon the top of the rear wheel, when a slight downward pressure is sufficient to bring the ladle to rest. By the use of well-laid rails, preferably without any inclines, and the above simple but effective brake apparatus, a large ladle, full to within a few inches of the top, may be conveyed from the cupola to the mould in a very short time, with very little power, so steadily as not to spill any of the contents; a very desirable result, on the score both of economy and of safety. The chains for moving the trucks along the railway are sometimes drawn by manual labor, but a more steady motion is obtained by winding the chain upon a barrel at the end of the line of rails.

The foregoing description and illustrations are taken from "A Treatise on Casting and Founding," by N. E. Spretson.

LAGGING. The clothing of a steam-boiler or cylinder, designed to prevent radiation of heat.

LAMPS. The introduction of kerosene as a means of illumination has so completely revolutionized many of the principles involved in the construction of lamps, that the old forms are now seldom or very infrequently seen. The many and varied improvements made up to the present date have been attained only after the expenditure of considerable ingenuity on the part of the inventors themselves, and by a clear perception of the physical laws relating thereto. To construct a good and serviceable lamp, certain essential principles must be kept in view. They are:

1. To select such a form of wick (the cylindrical being the best) that the quantity of decomposed oil and the simultaneous supply of air may stand in such relation to each other that the hydrogen and carbon may be consecutively consumed, and consequently no smoke produced.

2. To make the distance between the burning part of the wick and the surface of the oil as unchangeable as possible. This condition applies particularly to those varieties of lamps in which coal, lard, or fatty oils are fed to the wick either by pumps or hydrostatic pressure, and only in a minor degree affects those using refined oils.

3. To place the reservoir of oil in such a position that the shadow shall occasion little or no inconvenience. The use made of the lamp must, of course, here regulate its form. It is not, however,

always a fault when these do not exactly correspond. Thus the shadow thrown by a wall lamp is unimportant, as the lamp itself covers the shadow; in like manner, the shadow of a common study lamp cannot be considered as a fault, being used only by one person, although its prevention is always an improvement.

4. To throw the light radiating from the flame, by means of collectors and reflectors, from those parts where it is of little service in the direction where it is most required.

Crude-Oil Lamps.—Lamps which consume the crude oils are now seldom employed in the United States, their use being mainly confined to circumstances under which kerosene and burning fluids (on account of the comparatively low temperature at which they vaporize, and the agitation to which they must be subjected) become unsafe. For railroad, ship, and factory illumination, various forms are constructed, on any one or more of the following principles:

a. Owing to the consistence of crude oil, it is little affected by capillary attraction except over a short distance, varying with the oil used. Consequently the oil must be in the immediate vicinity of the burner.

b. In order to augment capillarity, the oil may be heated.

c. The oil is forced into immediate contact with the wick in tall lamps by means of pumps, or pressure exerted upon the body of oil, either mechanically or by equilibrium of fluids.

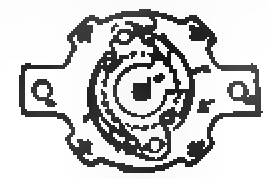
Pump Lamps.—In these lamps the oil is raised to the wick by means of a pump, operated usually by a clock-train. Many lighthouse lamps are of this description. One of the earliest standard forms was that devised by Carcel.

The Hitchcock Lamp, invented by Mr. Robert Hitchcock of Watertown, N. Y., in 1868, is an improvement on the Carcel lamp. Its construction will be understood from Figs. 2546 to 2552. It is a force-blast lamp for burning lard oil without a chimney, globe, or substitute for either. The same motor and pump supplies both oil and air at the point of combustion. A general sectional view of the lamp is given in Fig. 2546. Fig. 2547 is the movement, which is placed at the bottom of the lamp in a cylindrical air-jacket, A^2, Fig. 2546. G is the mainspring, wound by a key applied to the arbor G', which projects through the false bottom $H\,H$. The mainspring is placed in a revolving cylinder H, in a stationary tube J. On the top of this mainspring cylinder H is fastened an internal gear I, which drives a pinion 1 and its wheel 2, Fig. 2548, and throughout is driven by wheels and pinions ending at wheel 8, which operates

2546.

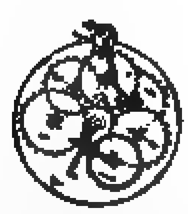
2547.

2549.



2550.

2548.



an endless worm 9, Fig. 2546. On this spiral is placed a fan or blower e, which is driven at a high speed (1,500 revolutions per minute) by the train of wheels and mainspring, which draws a current of air through the holes in the false bottom $H\,H$, along the air-jacket $A^2\,A^2$ through the blower at e, and is thence driven around the shield f, and up the flues d, d, d', d' to the burner C'. The oil is then forced up as follows: Fig. 2550 is an ordinary double-acting plunger-pump, with ball-valves k, k, and oil-pipes h, h, h, h, h^2, and a plate to hold the parts together. The plunger is operated by lever J, jointed at J'. This pump is placed in the oil-tank $A'\,A'\,A'\,A'$, Fig. 2546, and is made to move forward and back by a rock-shaft $r^1\,r^1$ and its armatures 10, 11, acting on pins in wheel 4. (See also Fig. 2548.) On the top of this rock-shaft is fastened a crooked arm $r^2\,r^2$, connecting with the pump-lever at J; thus, while this motor is driving air, it vibrates the pump-lever as described, throwing oil up through the oil-pipes h, h, h to the coupling h^2, and thence through the bent pipe l, delivering oil into the wick-tube $D\,D$, thence through the wick to the point of combustion, the excess of oil running down the outside and inside of the wick-tube D, dropping on the

shield-strainer g, into the shield f, and back to the tank $A' A'$, through strainer-pipe f^1. The lamp is filled at C; r is the stopple. The shield f serves to deflect the air from the blower s, and to carry back oil, also to prevent oil from gathering in the motor. The wick used in this lamp is the old solar, cylindrical wick, the exposure being three-sixteenths of an inch. The tube being compressed into an ellipse, the wick conforms to it, Fig. 2551, producing a batswing flame. The air is made to impinge from the inside by this form, and from the outside by the narrow slot in the burner at C', producing a silvery-white combustion, free from discolored spots or orange tints in the flame. The wick-raising device is common to all lamps burning heavy oils, having a long screw-nut and button $E E$.

Fig. 2549 is the winding-plate, with its clicks o, o', click-springs o^2, o^3, and ratchet-wheel o, and is attached to the bottom of the movement, Fig. 2547.

Fig. 2552 shows the lamp-top detached at K, the upper half containing burner and tube D, wick-

2552. 2553.

tube, and bent oil-tube as far as h^1, where it uncouples, in a socket, for the purpose of cleaning out matches, crust, etc., that accumulate with carelessness.

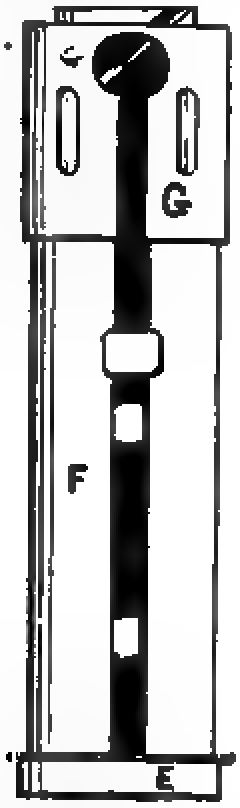
It is stated that by photometrical test this lamp has given a light equivalent to that of 17 candles.

Kerosene Lamps.—*The Student Lamp.*—The St. Germain or student lamp was invented by C. A. Kleemann in 1863, and has been much improved since by C. F. A. Hinrichs of New York. It is a common defect of most lamps that the oil-vessel is placed immediately under and close to the burner, a position which throws the most objectionable shadow. Many contrivances have resulted from efforts directed toward transposing this cistern above the level of the flame, when its shadow would fall upon the ceiling of the room, or to a position much below the flame, when the shadow would fall at the foot of the lamp. Both arrangements, however, give rise to new difficulties, the former requiring regulation of the supply and the latter the use of a pumping device. In the St. Germain lamp the reservoir is placed midway up and at a distance from the burner. By this arrangement the lamp is also rendered safe, as the vapor of the petroleum is entirely cut off from the flame, the supply-tube being constantly filled with the liquid.

Fig. 2553 is a representation of the lamp, and Fig. 2554 a sectional view. The oil-cistern A, Fig. 2554, is a movable metallic vessel capable of being closed at the bottom by a valve B, which moves by the rod depending from it. In the upright position the valve falls back and leaves the aperture open for filling the vessel; if the valve is then pulled up by the rod, the aperture is closed, and the cistern can be inverted and put in its place. The rod attached to the valve is of such a length that the valve is raised as soon as the rod touches the bottom of the case. The oil therefore flows out until it has risen so high in the case as to stop the opening of the supply-tube. From this moment equilibrium is established, and as the aperture is on a level with the height of the burner, this becomes filled at the same moment. The lamp has really two oil-cisterns, an under one which directly

feeds the burner, and an upper and inverted one for the supply of the chamber beneath as the oil is gradually consumed. As long as the level of the oil remains unchanged, and the mouth of *A* completely closed, no air can enter, the whole stock of oil being kept up by atmospheric pressure. When the lamp has been lighted some time, the oil sinks below the mouth of the cistern, and a few air-bubbles enter and take the place of an equal bulk of oil, which flowing again raises the level. The burner for this lamp is made for the round Argand wick, which is fastened over a thin sheet of

2555. 2556. 2557.



metal grooved to form a screw. The air-tube has a similar screw. Fig. 2555 represents the wick and detached screw. The wick is applied to the tube and fastened. Both are then placed in a slotted tube, Fig. 2556, and the button pressed down to the point *E*, which is screwed down over the air-tube. By grasping the chimney-holder and reversing the screw, the wick-tube and wick are raised. Mr. Hinrichs has patented and adapted a new wick which is non-combustible. The mineral wick is made by combining plaster of Paris, asbestos, sugar or similar saccharine material, and mineral wool. An ordinary wick of cotton conducts the oil to the base of the mineral wick; this wick requires a metal wick-tube and an outside case. Fig. 2557 represents the mineral wick and inclosing tube, and also the cotton supply-wick. The mineral portion protrudes for about three-fourths of an inch above the top of the tube. The advantages claimed for this wick are non-combustion, obviating the necessity of trimming, and the production of a better and more even light.

Among the improvements on this lamp may be noted a new valve for the oil-cistern *B*, Fig. 2558,

2559.

2558.

2560.

which consists of a semicircle of light brass, immediately above which, and loose on the rod, is a cork float *A*. When the reservoir is reversed for filling, the oil floats the cork, closes the valve, and so prevents an overflow of oil during the act of replacing the cistern.

Schneider's modification of the cistern consists in dispensing with the ball-valve and using a slide-valve in its place. Fig. 2559 is a section of the cistern. Fig. 2560 shows the method of filling the lamp with valve open. On the side of the valve-tube is a projection *D*. When the valve is open,

the arm B is at right angles to this projection. The outside cistern is so arranged interiorly that the cistern will not enter unless the valve-arm is in a line with the projection D, and consequently closed. The valve is opened by rotating the cistern; the valve-arm is now held by the slot in the valve-tube, which prevents the cistern from being emptied, should the lamp be upset. Fig. 2561 is

2561.

a representation of a drip-cup at the base of the reservoir, to catch any oil which from carelessness should run down the sides of the vessel. Fig. 2562 shows a ball-valve introduced into the arm connecting the reservoir and the burner at the point where it joins the burner, for the purpose of shutting off the oil-supply should the lamp be tilted.

The Cleveland lamp is similar in design to those described, having a slight modification of the wick-raising device, and a safety-gauge inserted in the wick-tube and oil-reservoir.

Round-Wick Burners.—Burners for kerosene lamps are constructed to carry either flat or round wicks. In the Argand or round-wick burner, the air to support combustion enters at a perforated ring at the base of the burner, and, passing through the inner tube, supplies the interior of the flame. These burners are varied by having the inner tube depressed below the outside tube, the perforation for air-supply being variously situated, as on the ring surrounding the base of the chimney or through the base of the lamp. The light produced by an ordinary-sized burner carrying a round wick can be roughly estimated at 12 candle-power. The chimney carried by these burners is a cylinder contracted immediately about the burner. The elevation of the wick is effected by a toothed wheel.

Burners requiring no Chimney.—Figs. 2563 and 2564 represent two forms of burners which require no glass chimney to steady the flame, an ascending air-current which surrounds the flame serving this

2563. 2564. 2565.

purpose. In Fig. 2563 this current passes through perforations, and in Fig. 2564 through slits in the burner.

The use of the chimney is obviated in a different manner by the device shown in Fig. 2565. Here the shade-holder is made to fit around the cone of the burner, and is attached thereto in the same manner as a chimney. Upon this the shade is placed, so that the shade and holder really perform the functions of a chimney, inducing a draught of air to the flame. Owing to the large size of the combustion-chamber thus afforded, it is stated that combustion is more perfectly secured.

Mineral-Wick Burners.—In Fig. 2566 the body of the burner is shown with the screw a for attaching the burner to the reservoir, and also the air-distributor b in the form of a perforated cap. The central stationary air-tube c is fastened at the lower end to the body of the burner, and openings are provided through the body at each side of the tube c for the wick-tubes e. In Fig. 2566 the wick-tube is segmented at its lower part, and extends up and terminates in an annular Argand-wick cylinder f, which contains the mineral wick i. In Fig. 2567 two rectangular wick-tubes e are employed,

connected together by plates w. The oil is supplied to the mineral wicks by means of a fibrous wick g. The wick-tubes are provided with rack m, which allows of elevating or depressing the wick by means of pinion and shaft $h\ l$. Lateral openings v are formed in the stationary air-tube adjacent to the cut-off plate w, the object being that when the wick-tubes are drawn down and the flame lessened, the central supply of air will be reduced by the plates w, partially or entirely coming down over the openings v. Thus the odor which is usually emitted immediately after the flame has been extinguished is diminished by reason of the circulation of air being cut off. On the burner shown in Fig. 2567, hinged fingers v^2 are employed, which are acted on by projections 10 on the wick-tubes, which, being drawn down these, cut off the flame, and prevent any escape of odor from the wick.

2566.

2567.

The Cleveland Lamp contains devices for cooling the oil as it approaches the burner. The oxygen, instead of passing to the flame just below the burner-cone, enters through apertures at the sides and near the bottom, enveloping the central or wick tube, and keeping the oil contained both in this tube and in the reservoir as cool as the surrounding atmosphere.

Kendall's Hydrostatic Lamp is so contrived that the oil floats on water, and is by the latter lifted up a tube to the burner, with which it is kept in close proximity, so that no space is afforded for the generation of inflammable vapor.

Vapor Lamps.—In these the vapor of petroleum, turpentine, gasoline, or other hydrocarbon is burned. In petroleum-vapor lamps the oil from an upper tank is fed to a chamber in which it is vaporized. It then issues from a nozzle, where it is ignited, the flame impinging upon and heating a plate from which arms extend down to the vaporizing chamber. The arms conduct heat to the chamber, and so keep it at a sufficiently high temperature to insure vaporization of the contents.

Lamps for Burning Various Substances, etc.—*Magnesium Lamps.*—The metal magnesium when in a state of combustion emits a light which is unendurable to the naked eye, and at the same time gives forth a cloud of its oxide, which eventually fills the apartment in which it is burned. Various attempts have been made to obviate this difficulty, and it is found that by alloying with zinc the fumes are more readily removed, while the quantity of light is undiminished. An alloy with thallium has also been successfully tried. Long strips of magnesium ribbon are usually coiled about a drum and fed by clockwork into the flame of a small alcohol lamp. In one form of magnesium lamp, the metal is employed in a pulverized state, and may be used either alone or mixed with sand, or with some material, as nitrate of strontia, to give color to the flame. It is placed in a funnel-shaped reservoir, from the lower part of which proceeds a long narrow tube, and at the lower end of this is a small spirit lamp. This serves to ignite and maintain the flame of the powdered magnesium, the flow of which is regulated by means of a small finger-tap, so as to increase or diminish the light as required. The spirit lamp also prevents the end of the tube from being fouled or stopped up by the oxide, which would otherwise form within and around it. The light emitted by a magnesium wire .001 inch in diameter is equal to that of 74 stearine candles of five to the pound.

The Aphlogistic Lamp.—In this a wick of platinum wire is kept constantly red-hot by the slow combustion of alcohol, heated by the wire itself.

The Hydrogen Lamp.—This consists of a vessel containing acidulated water, from the cover or cap of which is suspended a cylinder of glass open beneath. In the cylinder is hung a piece of zinc. An aperture in the cover over the cylinder is surmounted by a nozzle and stop-cock. Facing the nozzle is a hollow receptacle holding a piece of spongy platinum. When the acidulated water comes in contact with the zinc, hydrogen gas is generated, which gradually forces the water out of the inner cylinder, and so out of contact with the zinc, so that chemical action is stopped while the apparatus is out of use. On pressing the stop-cock a jet of hydrogen is directed upon the spongy platinum, which becomes highly heated and finally ignites the jet. This lamp is used as a convenient means of obtaining fire in chemical laboratories, etc., and not for illuminating purposes.

The Tar Lamp.—The tar is contained in a cylindrical case, and flows from thence by a pipe to the burner, at the summit of which it is ignited. The supply apparatus is on the fountain principle, and a chamber below the reservoir catches any overflow, which is drawn off by a faucet. A jet of air is introduced through the centre of the annular burner having a pressure of 1½ lb. to the square inch. This is admitted at pleasure by a faucet below. Without the central blast a small lambent flame is obtained; when the compressed air is admitted, the tar burns with a vivid white light.

Submarine Lamps are adapted to burn beneath the surface of the water. The submarine lamp used in exploring the breaches in the Thames Tunnel in 1825–'27 contained a spherical reservoir of condensed oxygen. The light was a wax candle. The lantern was entirely air- and water-tight. When about to descend, a solution of caustic alkali was poured into the lamp, and a small jet of oxygen was admitted to the light-chamber. Of the products of combustion, the carbonic acid was absorbed by the alkali and the water condensed on the sides of the glass; the oxygen mixed with the nitrogen to form atmospheric air. Oil-lamps constantly supplied with air by means of a forcing-

pump and the electric light have also been employed. The first was objectionable on account of the trouble it occasioned, and the latter by reason of its expense and the strong shadows cast by it. The lamp of MM. Leanté and Dénoyel is supplied with oxygen gas forced under a pressure of 10 atmospheres into a reservoir beneath, whence it is conveyed by a small tube to two annular receptacles, one inside and the other outside the wick. Each is pierced with a number of small holes. Simple devices regulate the motion of the wick and control the supply of gas. The whole is protected by a thick glass cover, so as to be air- and water-tight. Van der Weyde's submarine lantern has a cylindrical glass case, with the interior of which two channels communicate, one connecting with a flexible pipe through which fresh air is injected, and the other with a tube by which the products of combustion are carried off. A hydrocarbon compound is provided which volatilizes readily by heat.

Lamp for Burning Nitric Oxide Gas.—The brilliancy of the light produced by the combustion of nitric oxide gas has been known for some time, and its application to photographic purposes suggested; but it was not until Messrs. Delachanal and Mermet recently constructed a suitable apparatus that it could be made practically available. They use a lamp made of a pint bottle, having two openings through the cork, and filled with fragments of some porous substance, as sponge, coke, or pumice, for the purpose of imbibing the sulphide of carbon. A tube, reaching within one-fourth of an inch of the bottom, passes through one opening in the cork, and a larger one through the other opening. This is about 8 inches long, and may be of glass or metal, and is closely packed around with iron scale. The object is to prevent the return of the flame into the bottle, and its consequent explosion. The nitric oxide gas is passed into the bottle through the first-mentioned tube, and the gaseous mixture is conducted by a rubber tube to a kind of Bunsen burner, the air-holes of which are closed, and which is furnished with a small conical valve to regulate the flow of gas. The burner is also filled with iron-scale. The nitric oxide gas is produced by Sainte-Claire Deville's method, by the action of a mixture of nitric and sulphuric acid upon metallic iron. With an apparatus of quite moderate dimensions a dazzling flame, not less than 10 inches in height, can be obtained, abundantly sufficient for the purpose of photographic work. It has been estimated that the photographic power of the lamp is superior to that of magnesium, is twice as great as that of the oxyhydrogen light, and three times as that of the electric light. Furthermore, the flame is absolutely steady, and there is no danger of its sudden extinction, as with magnesium. Its cost is said to be much less than that of either of the other lights.

Nitric Oxide and Bisulphide of Carbon Lamp for Photographic Use.—A small spherical glass vessel filled with bisulphide of carbon is supplied with a wick, by which it is fed to a burner, through the centre of which nitric oxide is admitted from a gasometer by means of a tube bent at right angles. This globe is inclosed in a larger one of glass filled with cold water, to cool the bisulphide. Upon lighting the bisulphide, which can be done without danger, and then regulating the flow of nitric oxide and the height of the wick, a beautiful white light of great intensity may be produced. This lamp, patented by Sill in England, is used principally for photographing, the exposure required being very slight. The light is very rich in refrangible rays, and the negatives are said to be all that can be desired as to the distribution of light and shade.

The Phosphorus Lamp.—A safety-lamp for use in magazines, or where inflammable materials are stored, can be prepared in the following manner: A clean glass vial of oblong shape is filled with boiling olive-oil to about one-third of its volume; into this is dropped a piece of phosphorus about the size of a pea, upon which the vial is tightly closed. When it is required for use, the cork is removed, the air is allowed to enter, and the vial recorked. The empty space above the liquid will then be found to become luminous.

Oil and Oxygen Lamp.—Van Lenac of Paris has devised an oil lamp with a burner so constructed as to admit a jet of oxygen directly into the interior of the flame. The light produced was perfectly steady, and so intense that a gas-flame appeared yellow by contrast.

Lamp Shades are screens placed around the light to reduce or mellow it. The commonest are those made of white porcelain, which both reflect the light downward and also reduce the intensities of the rays transmitted through them. For the illumination of show-windows in shops, reflecting shades are made of corrugated metal having a brightly silvered interior surface. Where the shade is of transparent material and entirely surrounds the burner, the loss of light depends upon the material used.

Table showing Loss of Light by the Use of Shades and Colored Media (Storer and Stevenson).

MATERIALS.	Thickness, Inch.	Loss per Cent.
American enameled glass	$\frac{1}{11}$	51.23
Crown-glass	$\frac{1}{8}$	18.08
Crystal plate-glass	$\frac{1}{8}$	8.61
English plate-glass	$\frac{1}{8}$	6.15
Transparent porcelain	$\frac{1}{14}$	97.68
Parisian porcelain, pink tinge	..	57
Deep-red porcelain	..	80
Window-glass	$\frac{1}{16}$	4.27
" " green	$\frac{1}{16}$	81.95
" " ground	$\frac{1}{16}$	65.95

LIGHTHOUSE LAMPS.—Each lens light in the three largest orders of lighthouses is illuminated by a mechanical moderator, pneumatic or hydraulic lamp, with the burners so placed that the centre of the flame when at its normal height will be in the common focus of the apparatus. All these lamps are furnished with multiple wicks, varying in size and number according to the order of the apparatus. The several kinds of lamps employed differ only in the mechanical contrivances, which in all have the same object, namely, to supply oil at a given rate of consumption; their moving power is a

weight working inside the hollow support, a spiral spring, or a float for regulating the flow of oil to the burner.

Funck's Hydraulic Lamp, Fig. 2568, is one of the most improved forms used in the U. S. Lighthouse Service. *A* is the supply-reservoir, *B* the supply-tube, *C* the float-chamber, *D* the float, *E* the burner, and *F* the overflow-reservoir. The supply-reservoir *A* is made to hold twice the quantity of oil that can be consumed during the longest night, including the waste by overflow. It is filled in first- and second-order lamps by means of the hand-pump *G*, which is placed inside of the overflow-reservoir. The supply-tube *B* connects the supply-reservoir with the chamber *C*. A section of the float-chamber and burner is shown in Fig. 2569. The float *D* is made perfectly air-tight, and is perforated throughout its entire length by a tubular space and suspended from the valve-stem by a cross-bar. At its upper end the valve-stem terminates in a conical valve, which is inclosed in a valve-chamber. The latter communicates as shown with the supply-tube and with the float-chamber. The oil passes from the supply-reservoir through the supply-tube into the valve-chamber; then, owing to the notches in the valve, along the grooves in the valve, into the float-chamber without coming into contact with the surface of the float, and its flow becoming checked. By hydraulic pressure the oil rises to a level, which, in order to secure an overflow, is a little above the top of the burner, carrying at the same time the weight of the float, and raising the valve to a height at which it admits the oil to the burner in sufficient quantity to support good combustion, and a moderate overflow to prevent overheating of the burner and too rapid carbonization of the wicks. Fig. 2570 is a section of a first-order burner, showing the arrangement of the four wicks.

2569.

2570.

Mechanical Lamps.—In mechanical lamps, the machinery is in general contrived to turn a vertical arbor, which by cranks and connecting-rods communicates a reciprocating motion to the piston-rods of the pumps. The consumption of oil in a mechanical lamp producing its full effect is nearly, with sperm and colza oil, for a lamp of first order, 760 gallons per annum; second order, 503 gallons; and third or less (large), 179 gallons. To enable the flame to produce its full effect, and at the same time to keep the crown of the burner sufficiently cool, the pumps should deliver nearly four times as much oil per hour as the lamp consumes.

Height of Flame.—The maximum heights of the flames produced by burners of the different orders are as follows: First order, 3.5 to 3.75 inches; second, 3 to 3.25; third, large, 2 to 2.75; third, small, about 2.5; fourth, 1.75 to 1.8; fifth, 1.5 to 1.75; sixth, 1.5 to 1.75.

The height of flames of ordinary Argand fountain lamps of beacons and light-vessels, corresponding to the full effect of these lamps, is from 1.5 to 1.6 inch.

For details of construction of various forms of lamps, instructions for their management, etc., see "Instructions and Directions to Lighthouse Keepers," Washington, 1871. G. H. B.

LAMPS, SAFETY. The explosive mixture of light carburetted hydrogen and atmospheric air which is often present in coal-mines long made it desirable to procure some kind of device by which the ignition of the compound might be avoided. Contrivances called steel mills were first used to give light in dangerous parts of the mines, a succession of sparks being constantly elicited by the rapid revolution of little wheels of steel against pieces of flint. In an explosive mixture of gas and

air these however were not safe, as the sparks were liable to produce explosion. Their greatly increased brilliancy in this served to indicate danger; and where the gas predominated above the explosive proportion, the sparks were of blood-red color or ceased entirely to be emitted. The necessity of more efficient protection led to the invention in 1813, by Dr. W. R. Clanny of Sunderland, England, of the first true safety-lamp. In this the communication with the external air was intercepted by water, through which the air was made to pass. This apparatus proved too cumbrous for general use. In 1815 George Stephenson and Sir Humphry Davy both invented safety-lamps on other principles. The former, noticing the effect of the gaseous products of combustion to extinguish the burning jets of inflammable gas called blowers, which issue from the crevices of coal-mines, contrived a lamp which was protected by a glass cylinder, and covered at top with a perforated metallic cap to allow the products of combustion to pass out. The air to support combustion was admitted through small openings in the bottom, and it was supposed that the velocity of the current entering the lamp would prevent the explosion passing backward; but the protection the lamp afforded was really owing to the smallness of the apertures, continued through capillary tubes till they discharged all around and close against the circular burner. Davy's lamp is represented in Fig. 2571. The wire-gauze cylinder, through which the air was admitted, served also for the passage of the light, and when composed of wire $\frac{1}{40}$ to $\frac{1}{60}$ of an inch in diameter, and with 28 wires or 784 apertures to the inch, proved a perfect obstruction to the flame in the most explosive mixtures, unless these were blown in currents through the gauze, or the lamp was carried rapidly through the gas. The wires might even be heated red-hot, as sometimes happens in very foul air, by the flame leaving the wick and burning in the upper part of the cylinder, and no explosion take place; but if a glass cover became hot, it might be broken by drops of water falling upon it; and so fragile a material under any circumstances could not be regarded as a sure protection.

2572. 2573.

2571.

Among the various modifications of the Davy lamp, that known as Mackworth's safety-lamp, which was contrived by one of the government inspectors of coal-mines to meet the objections raised in resisting the general introduction of the Davy lamp into the fire-damp mines, is represented in Fig. 2572. The objections were the small light given by the Davy, which is an inconvenience in working high seams of coal; that its locks could be easily picked and opened by the workmen to obtain more light, or to light their pipes; and also the danger of breaking the glass already mentioned. The lamp has a thick outer glass, *a a*, and a thin inner chimney, *f b*. The air supplies the flame in the direction of the arrows through three wire gauzes: first through the cylindrical gauze *c*; then through the gauze *d*, which supports the brass cover *e* of the glass chimney *b*; and thirdly through the conical wire gauze *f*, which with its frame acts as a support to the glass chimney *b*. This conical frame throws the air on to the flame *g* so as to produce a more perfect combustion and a white light. This lamp burns with a steady flame in currents of air which extinguish other lamps. It is 1½ lb. heavier than the Davy, and 1¼ lb. lighter than the Clanny lamp. The outside glass does not get so hot as in the latter; and if it breaks, there is still a perfect safety-lamp inside.

Fig. 2573 shows the type of lamp known as the "Clanny," with the protector principle added. *A* is the wire-gauze; *B*, the glass cylinder below it, bedding on the plate *C*, which is provided with an aperture *D*, screwed to receive the extinguisher-tube 4. This tube is, in turn, provided with a coarse thread to receive the burner. The reservoir is filled with a sponge *O*, in connection with a permanent wick *N*, reaching to within a short distance of the top of the burner, the remaining space being occupied by a short asbestos wick *M*, which, though unconsumable, may be renewed should occasion require. The protector principle consists in its being impossible to remove the lower or reservoir portion of the lamp from the upper, without at the same time extinguishing the flame; and this is accomplished in the following manner: When the lamp is trimmed and lighted, with the extinguisher-tube screwed in its place over the burner, all these parts together are screwed into the plate *C* of the upper portion, from which they may be again withdrawn as long as the bolt *G*, sliding in the projection *F*, is kept clear of the extinguisher-tube. Directly, however, this is shot home, its hollow curved end occupies the space between the flanges of the extinguisher-tube, and prevents the tube from following the burner on the latter being unscrewed. The consequence is that, on the burner being drawn below the tube, even to the extent of one-third of an inch, the flame becomes extinguished owing to its being deprived of the oxygen necessary to support combustion. The bolt is retained in its place, after being shot, by the small spring flying out and butting against the portion marked *E* of the casing. (For other forms of lamps, see *Engineering*, xxvii. 423.)

The main points to be considered in a miner's safety-lamp are the following: 1. The flame should be protected with a covering the density of which is sufficient to absorb the heat from and reduce

the temperature of the flame, so as to render it incapable of igniting explosive gas, while at the same time the rays of light are allowed to pass through as freely as possible. 2. The fuel for supporting the flame should be of such a nature as to insure perfect combustion. 3. The lamp should be so constructed that it cannot be tampered with in the pit in such a way as to expose a flame, which, on coming in contact with the gas, would cause an explosion. A simple method of testing safety lamps consists in placing at the bottom of an open jar a small quantity of petroleum spirit, the vapor of which mingling with the air of the jar forms an explosive mixture. The lamp is plunged into the jar, and any defect in its protector is at once shown by the occurrence of a slight explosion.

LAPPER. See Cotton-spinning Machinery.

LAPPING. See Carpentry.

LATHE, METAL-WORKING. The distinctive names applied to the principal forms of metal-working lathes are as follows:

I. *The foot-lathe*, which is sufficiently small and light to be worked by the foot of the operator.

II. *The hand-lathe*, wherein the operation of turning is performed by hand-tools and appliances, and which has no self-acting feeding device to hold and guide the cutting-tool.

III. *The self-acting lathe*, which has mechanical contrivances for holding the tool and causing it to advance over the object being turned.

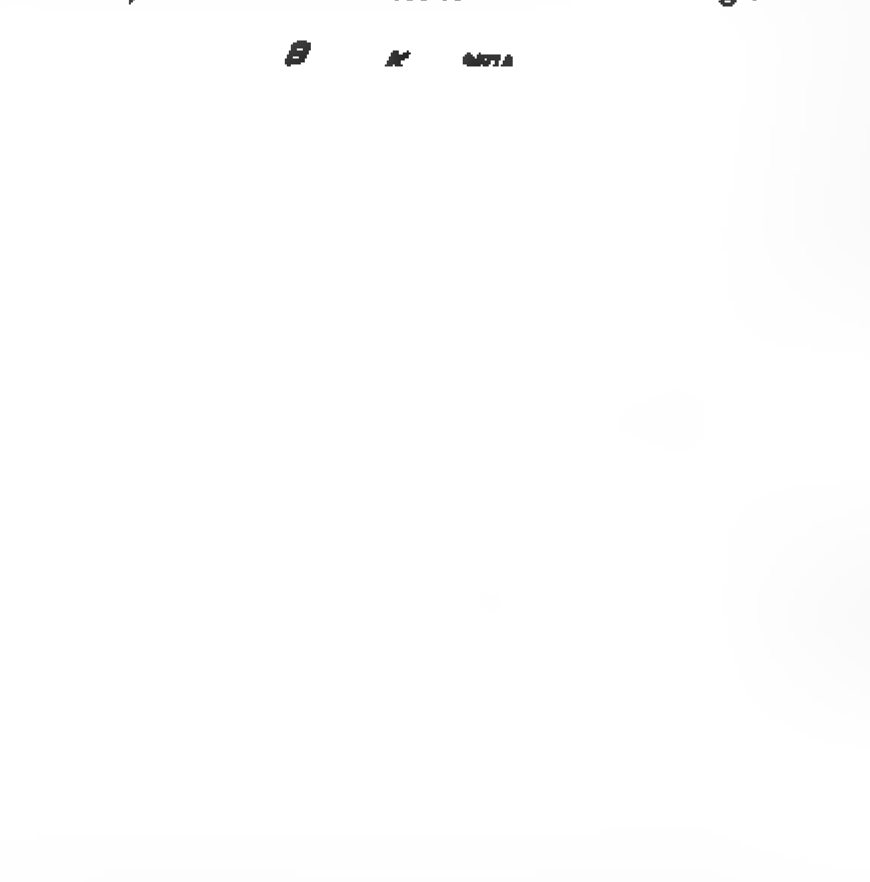
IV. *The chucking or face lathe*, designed to carry heavy or large work fastened to the face-plate or chuck.

V. *The boring lathe*, designed to operate mainly upon internal cylindrical surfaces.

Any of these lathes may be included in classes termed respectively single-geared or back-geared; the first denoting that the lathe is supplied with a cone or stepped pulley, unaccompanied by any gear-wheels for reducing the speed of the lathe-spindle, as is requisite when turning work of large diameter or of hard metals; the second indicating that the lathe is provided with such gear-wheels.

The essential parts of a lathe are the *head-stock*, containing the driving-cone and *live* or revolving spindle; the *tail-stock*, supporting the back centre; and a bed or frame carrying these two stocks. The necessary adjuncts to a lathe are rests whereon to sustain or carry the cutting tool, chucks whereon to fasten work requiring to be held, and various other special devices which will be noted elsewhere.

The Foot-Lathe.—In Fig. 2574 is shown a foot-lathe. *A* is the bed, *B* the head-stock, *C* the tail-stock, and *D* the hand-rest to sustain the cutting or turning tool. *E* is a treadle to be operated by the foot, being pivoted for that purpose at *F F*. *G* is a chain connecting the treadle to the crank shaft *H*. *I* is a stepped pulley connected by belt or band to the cone-pulley of the lathe. The pressure of the foot is applied to *E* upon its down stroke, causing *H* and *I* to revolve and to communicate motion through the belt to the cone-pulley. The wheel *I* is made of sufficient weight to act as a fly-wheel, and lift the treadle during the return and upward stroke, when the pressure of the foot is again applied to *E*, thus causing continuous rotary motion. The work is either fastened to the face-plate *K* or its equivalent in the form of a chuck (see Lathe-Chucks), or it is held between the centres. These centres are conical and pointed plugs, one of which fits into the live spindle and the other into the dead spindle; the latter is shown at *L*, and the former is hidden in the figure by the face-plate. Work to be placed between the centres receives a conical indentation at each end of its axis, and is suspended by being so placed that the centres fit into these indentations. The cutting tool is held in the hand and sustained upon the rest *D*, while its sharp edge is pressed against the revolving work. The tool is held firmly to the upper surface of the rest *D*; hence not until it has turned the work to a circle concentric with the conical indentation will the tool-edge have contact and perform cutting duty upon the whole circumference. If the conical indentations are not in the centre of the ends of the work, or if the latter is not round, so that the fixed tool-point touches only one part of its circumference during a revolution, the work is said to be *out of truth*. To set the lathe to hold different lengths of work, the tail-stock *C* may be fastened to the bed *A* by means of the hand-screw shown at *M*, at any required distance from *K*; and the rest *D* may in similar manner be moved along and fastened at any point upon the bed surface to suit the part of the work requiring to be turned.



2574

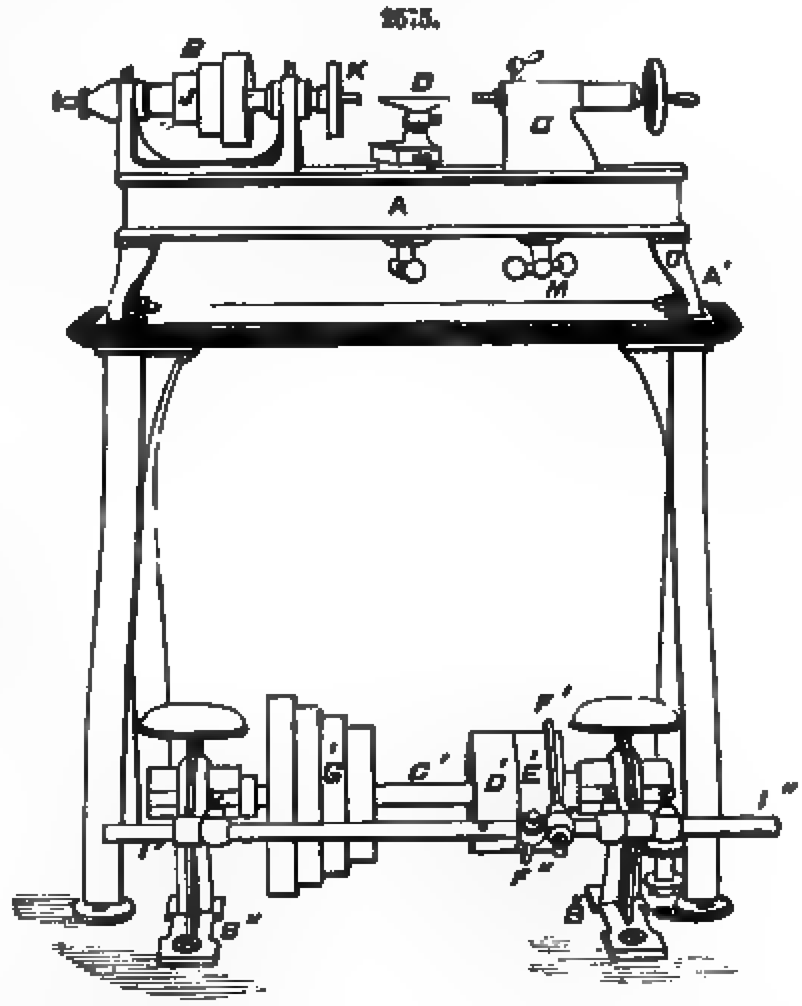
The Hand-Lathe.—In Fig. 2575 is shown a hand-lathe of the pattern made by the Pratt & Whitney Company of Hartford, Conn. The double frame is designed so that the lathe may be detached from the legs and tool-trough at *A'*, and bolted to a bench or elsewhere. To drive lathes other than foot-lathes, a counter-shaft is employed, shown in the figure at the foot of the lathe.

METAL-TURNING LATHE.

THE SELF-ACTING LATHE.—The following illustrations relate to an improved self-acting lathe constructed by William Sellers & Co. of Philadelphia.

Fig. 2576 is a side elevation and Fig. 2577 is a plan view of the head-stock of this lathe. H' is a gear-wheel attached to S for the purpose of driving the feed-motions of the lathe-carriage. The train of wheels between H' and the feed-screw are termed the change-wheels, because there are a number of these wheels of the same pitch of teeth but of different diameters, or, what is the same thing, containing different numbers of teeth; and only those are placed in position on the lathe whose numbers of teeth are those necessary to effect the proper ratio of revolutions required under any given circumstances to be maintained between the live spindle and the feed. In Fig. 2576, J is the cone or stepped pulley, which is driven by the belt. It is fitted a neat working fit to the live or running spindle S, and revolves thereon unless attached by a suitable device to the gear-wheel C'. The pulley is stepped so as to render it possible to alter the speed at which J will revolve by placing the driving-belt upon the steps 1, 2, 3, 4, or 5, as the size of the work may require. The wheels D' and E', Fig. 2577, are termed the back gear, and their office is to reduce the speed of the lathe. When the wheels D' and E' engage with C' and F', Fig. 2576, the lathe is said to be in gear, and the cone J revolves upon the spindle S. F', which is fast upon the cone, rotates D', which is fast upon the same shaft as E', and E' rotates C'. This gives five speeds with the cone and five with the back gear, in addition to which five more are obtained by means of a pinion upon the end of the shaft G' engaging with the gear-teeth upon the face-plate C'. The whole fifteen speeds are so regulated that the rate of decrease or increase is uniform throughout the series. In Figs. 2578 and 2579 is shown the construction of the tail-stock of this lathe. Its office is to sustain one end of all work that is turned between the centres. In Fig. 2577, P' is called the live centre because it revolves with the live spindle S; and in Fig. 2578, P'' is called the dead centre, because it is stationary with the spindle B''. Given a piece of work of a certain length, the tail-stock A', Fig. 2579, is moved upon the lathe-bed (as the casting carrying the head-stock and tail-stock is termed) to about the proper position, and is there bolted by means of the nuts N' N'. Then conical cavities being made in the ends of the work, one cavity is placed over and upon the live centre; and the other end of the work having been brought in line, the dead centre P'' is screwed outward into the other cavity; and thus the work is suspended between the two centres P' and P''. To operate the back or dead centre, the spindle B'', Fig. 2578, is made a neat sliding fit in the tail-stock, and at one end of this spindle is provided a nut, into which the thread or screw G'' (Fig. 2578) fits. This screw has journal-bearings in the tail-stock at E'', and is provided with the collar shown on the inside, while the face of the hand-wheel D'' forms a collar on the other side of the journal. Hence, by revolving the wheel D'', the spindle B'' is made to pass out from or recede into the tail-stock. Now the spindle B'', being a sliding fit in the tail-stock, will in time become loose therein by reason of the wear; and it is therefore necessary, after the work is in position between the centres, to lock the back centre firmly in place, for which purpose the device shown in Fig. 2578 is provided. The front of the poppet-head or tail-stock is furnished with a threaded end or boss, through which the spindle passes, and over which a brass nut is screwed by a handle H''. The hole in which the spindle moves is bored bell-mouthed at the front end, and in this taper hole

2575.



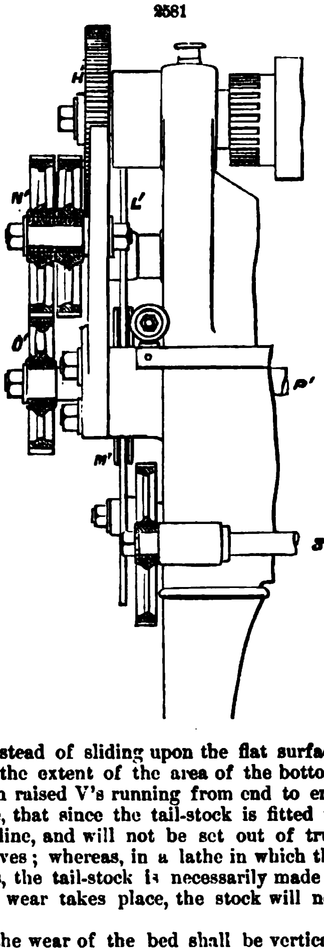
there is fitted a small split steel collar or ring turned to the same taper. Now, as the nut is screwed on, a projecting flange upon it forces the steel ring farther into the taper hole, and thus causes it to clamp the spindle; while a half turn back unscrews the nut a little way, and enables it to spring out by its own elasticity, thus relieving the pressure on the spindle at once. Less than half a turn of H'' is enough either to fasten or loosen the spindle; and it is worthy of note that this device clamps the spindle as nearly as possible to the point of thrust, and never exerts any influence to throw it out of line or centre or to spring it. The centres P' and P'' are fitted to a conical or taper hole in the respective spindles. Some kinds of work cannot be turned between the lathe-centres, but require to be chucked, that is, fastened by means of bolts and nuts and plates of iron to the face-plate of the lathe, or else to a table or frame provided especially for the purpose. In Fig 2577, C is the face-plate upon which work may be chucked. When, instead of a face-plate, an equivalent is used containing movable jaws or other attached devices for holding the work, the term chuck-plate or chuck is used instead of face-plate.

2579.

The details of the slide-rest construction are shown in Fig. 2580, in which A A represents the lathe-shears, B a carriage which slides thereon, and C a slide operated at right angles to the length of A A by means of the screw S, which is termed the cross-feed screw. To the slide C is attached the slide-rest R' and R. R' is provided with a slide along which slides R, operated by the screw O, which is worked by the handles H. T'' is the device for holding the steel cutting tool. The carriage B slides along the bed of the lathe for the purpose of traversing the cutting tool along the revolving work. C is operated to adjust the depth of the cut by means of the screw S' and handle

H', and R may be used for the same purpose. It will be noted, however, that the rest R' is held to C by bolts. This is done to enable the rest (when designed for the purpose) to be swung around so that the direction of the slide and hence of the screw O may be at any desired angle to the length of the shears $A\ A$. When a slide-rest is thus constructed, it is termed a compound slide-rest, and the upper or compounded part R' and R is employed to turn tapers or cones, the planes of whose exterior or surface are at an angle (other than 90°) to the length of the shears $A\ A$. In some lathes the screw S' is operated by mechanical means, in which case the lathe is said to have a self-acting or automatic cross-feed. "Screw-cutting lathe" is a term applied to lathes especially adapted to cutting screws. In the lathe under consideration there are two motions for traversing the slide-rest, one of which is by means of the spindle shown at S'' in Fig. 2581, operating a pinion in a rack. The changes of speed necessary to this feed-spindle are obtained by means of the friction-disks shown at L' and M', while the change gear-wheels for operating the screw-feed are shown at N' and O'. Both of these feed-motions are operated primarily by the gear H' attached to the end of the lathe-spindle. The feed-screw P' rests in a trough, preventing it from sagging, which would operate to cause the threads cut by the lathe to be of greater fineness than that due to the speed and pitch of the feed-screw, or rather lead-screw, as it is often termed. The object of providing two feed-motions is to use the screw-feed for cutting threads only, and thereby preserve it from deterioration by unnecessary wear; it being obvious that the truer and less worn the feed-screw is, the more accurate in pitch will be the screws or threads cut in the lathe. To traverse the slide-rest by hand, the hand-wheels shown at H and H', Fig. 2580, are provided, being attached to a spindle having journal-bearings in the saddle or carriage as shown in section, and having a pinion gearing into the rack.

2581



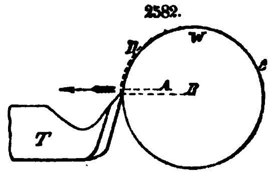
If the running or live spindle of a lathe revolved absolutely true in its bearings, if the tail-stock and slide-rest were in perfect contact with the bed, if the tail-stock were in true line with the head-stock, and if the slide-rest moved parallel with the line of centres of the head- and tail-stock, there being no lost motion in any of the working parts, or spring to the tool, the work would be cut perfectly clean and geometrically true. Therefore, in precise proportion as these conditions are fulfilled in the construction of a lathe will its performance approach perfection. The main points to be looked to in construction consequently are, that the tail-stock shall fasten to the bed in true line with the counter-line of the live spindle, and that the locking of the dead-centre spindle shall not cause that spindle to deviate from that true line. The slide-rest must be so fitted to the shears that it will, in traversing along the latter, move parallel to the same line. As the head- and tail-stock of the latter are firmly bolted to the bed, it follows that the weak point in the connection of the parts lies in the manner of adjusting the carriage, or saddle as it is sometimes called, to the bed. It is at this portion that the most wear takes place, and especially between the saddle and the bed, from directly beneath the running centre of the lathe over a distance of about half the length of the bed, extending toward the tail-stock; because in the shorter lengths of work this part of the bed only is in use, and it is not often, except for special employments, that the full length of the bed or shears is traversed by the slide-rest. The area of contact between the saddle and the bed has an important bearing, because a small area of contact acts as a weak section upon which vibrations have a more perceptible effect. In many lathes, however, the saddle or carriage, instead of sliding upon the flat surface of the bed, and thence having wearing surface and contact to the extent of the area of the bottom face of the carriage, is provided with V-grooves which fit upon raised V's running from end to end of the bed. The advantages sought by this arrangement are, that since the tail-stock is fitted to the same raised V's upon the lathe-bed, it will always be in line, and will not be set out of true laterally from any wear that may take place in the V's or grooves; whereas, in a lathe in which the tail-stock fits between the edges of the two sides of the shears, the tail-stock is necessarily made a working fit to enable its sliding along the bed, and when any wear takes place, the stock will not adjust itself dead true laterally with the running head

Another advantage sought by the adoption of V's is, that the wear of the bed shall be vertical, and therefore in a direction to have the least effect upon the work. Suppose, for example, that in Fig. 2582 W represents a piece of work and T a turning tool. The difference in the height of the tool due to the wear of the bed would have a very slight effect upon the diameter of the work. Let the wear be represented by the vertical distance from A to B, the tool-point standing at A at the commencement of the cut, and at B at the other end or termination of the cut; then it is apparent that the variation in diameter would be less than if the amount of wear upon the bed were in a lateral instead of in a vertical direction. This is because in the former case the tool-point, instead of dropping during the length of the cut from A to B, would recede from the circle C to that denoted by D. It is to be noted, however, that to cause the wear of the V's to be vertical only, the pressure

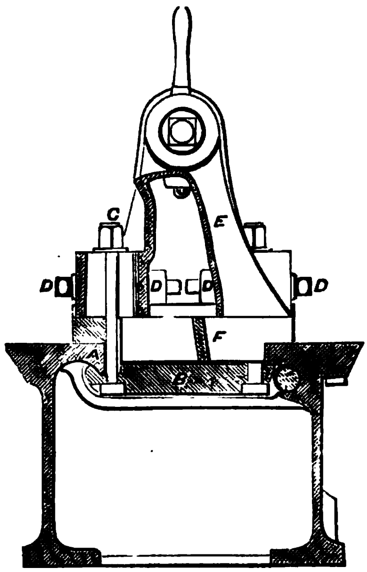
likewise would require to be vertical. Such, however, is not the case, except where a tool having a maximum of side rake (as in Fig. 2582) is used. While employing all other forms of tools, the direction of the drain on the slide-rest will be lateral as well as vertical, and the wear of the lathe-bed or ways will vary accordingly.

The form of construction followed in the lathe shown in Figs. 2576 to 2581 is as follows: The bed or shears is planed and fitted true from end to end. The head-stock is bolted firmly and permanently to the bed, the spindle standing exactly parallel to the length of the shears. Upon the perfection of workmanship of the live spindle and its bearings depends the possibility of turning the work truly cylindrical, and any imperfection in the roundness of the bearing will be reproduced upon the work. As the spindle is subject to continuous wear, it is important to construct it with a view to withstanding such wear as much as possible; hence it is made of steel, hardened, and ground up true afterward. The bearings are made of

2582.



2583.



steel accurately trued after hardening. To prevent the spindle from getting end play, the back bearing is made conical, and a stationary collar of hardened steel is secured to the spindle back of the back bearing. This collar is ground true and runs between hardened steel plates, preventing lost motion or end play, and obviating the necessity of providing the spindle with collars at the ends of the front bearing. This has a twofold advantage: first, it permits the spindle to pass through the front bearing to accommodate any expansion or contraction in its length due to variations of temperature between the spindle and the head-stock; and secondly, it does away with the tail-screw sometimes employed instead of the steel collar, the end of the spindle being thus left free to receive the change-wheels necessary for screw-cutting.

To maintain the tail-stock, or back head of the lathe, as it is sometimes called, in true line with the head-stock or running head of the lathe, when fastened on any part of the length of the bed, the following excellent plan is adopted: In Fig. 2583 the shear is shown provided with a V, and the clamp *B* is provided with a corresponding V; so that when the bolt *C* is tightened it draws these two V's together, insuring that the back head shall stand exactly in line, while at the same time that head fits down upon the flat surface of the lathe-shear. To turn tapers, the back head requires to be set over out of line with the running head, and this is effected as follows: The back head is constructed in two pieces, *E* and *F*. *E* is capable of sliding upon *F*, and after adjustment is locked by means of the bolts and nuts denoted by *D*. It is obvious, however, that short tapers may be turned without moving the back head out of line, by swinging the slide-rest out of line as already described. When the back head is placed out of line to enable the latter to turn taper, the work is liable to get out of true because of the lathe-centres not standing true with the centres of the work. Hence a special device, termed a *former-attachment*, is added to lathes constructed to turn tapers or irregular forms. This device may be improvised for almost every construction of engine-lathe by giving play to the nut which works the cross-slide of the slide-rest, and allowing a projection from this nut to press against a stationary *former*, either in the bed or on its upper surface, as is most convenient. The slide is pressed against this former-bar by a cord over a pulley, a weight being attached to the cord. This arrangement permits ready adjustment of the tool to its feed, while the motion of the tool is governed entirely by the former-bar, which if parallel with the bed produces a cylinder; if at an angle, a cone.

The Chasing Lathe (Sellers) shown in Fig. 2584 is designed to turn, bore, drill, ream, and tap brass-work, held, or as commonly termed chucked, either upon the face-plate or in chucks of a conformation designed to suit special work. The back head or tail-stock serves instead of a slide-rest, the turning tool, tap, reamer, or drill occupying the place usually occupied by the dead centre. To hold these tools firmly, the back spindle is made square, and the bearing on which it operates is adjustable to take up the wear. The upper part of the tail-stock sets over to enable the turning tool to move laterally to suit the diameter of the work. To cut external threads, the chasing-bar *A* and slide-rest *B* are provided at the back of the lathe, the latter firmly attached to the former. To cut different pitches of thread, the bar *A* is provided with hobs of different pitches operating on a stationary nut, thus causing *A* to move lengthwise at a speed corresponding to the pitch of the thread of the hob; hence, single, double, triple, or quadruple threads may be cut with equal facility. In operation, the rest *B* is pulled over to the work when traveling forward, and pushed back (partly rotating *A*) on the backward motion, which is so arranged that the hob and nut are thrown out of contact, enabling the bar to be traversed back by hand with a very quick motion, instead of feeding back

with a reversed motion of the screw. The bar *A* is counterweighted so as to press either toward or away from the centre line of the lathe. By a suitable device the slide-rest may be adjusted so as to be incapable of carrying the tool beyond a certain distance from the centre of the work, so that when once set the work may be cut to its proper diameter without requiring to be gauged or calipered. As an example of the operation of this tool, a piece of brass may be bored, tapped, and

2584.

screwed externally, or other operations performed upon it, at one chucking; the size of the boring, tapping, and screwing being standard, because of the standard sizes of the tools used, and of the adjustment of the slide-rest or of the tail-stock, as the case may be. The addition of a hand-rest is provided to enable the workman to perform with facility such slight operations as rounding edges or chamfering them, as required. The work turned out of a lathe of this class is of standard dimensions, and the parts are therefore interchangeable; while in quantity it is vastly greater than that obtained from an ordinary lathe under even the most skillful operation.

Change-Wheels for Screw-cutting in the Lathe.—The pitch of a screw is the distance between two adjacent threads. It is usually designated by the number of threads contained in an inch of length. With reference to its screw-cutting wheels, a single-geared lathe is one in which the driving-gear is either fastened upon and revolves with the cone-spindle, or is driven by an intermediate gear-wheel of such size that the driving-gear, though not fast upon the cone-spindle, yet makes the same number of revolutions per minute as does that spindle. At the same time the train of wheels is a single one, there being no two wheels of different diameters running side by side. In such a lathe all the changes in the wheels required to cut threads of different pitches are made upon the driving-gear, or upon the gear affixed to the feed-screw; the intermediate wheels having no other effect save to communicate motion from the driving-gear to the feed-screw gear. Hence, having ascertained what sizes of wheels are required for the driving-gear and the feed-screw, they may be connected together by means of any other gears irrespective of their sizes It will be perceived, then, that if the driving-gear and the feed-screw gear contain respectively the same number of teeth, the lathe will be geared to cut a thread of the same pitch as that of the thread on the lathe feed-screw, because the feed-screw will revolve at the same speed as the lathe head or spindle. Now, in proportion as the feed-screw revolves slower than the cone-spindle will the thread cut by the lathe-tool be finer in pitch than that on the feed-screw, and *vice versa*. Hence, to find the wheels necessary to cut a thread of any required pitch in a single-geared lathe, we have the following rule:

Divide the pitch of the thread required by the pitch of the feed-screw, and use the product as a divisor to the number of teeth contained in the wheel already upon the feed-screw, and the last product will be the number of teeth required in the driving-wheel.

In Fig. 2585, *a* represents the end of the cone-spindle, and *b* the feed-screw; *c* is the driving-wheel, and *d* the feed-screw wheel.

Example.—Suppose that, the pitch of the feed-screw being 4 to an inch, it is required to cut a thread of 8 to an inch, the wheel *d* containing 80 teeth, how many teeth will *c* require to contain? *Ans.* $8 \div 4 = 2$; then $80 \div 2 = 40$, the number of teeth for the wheel *c*.

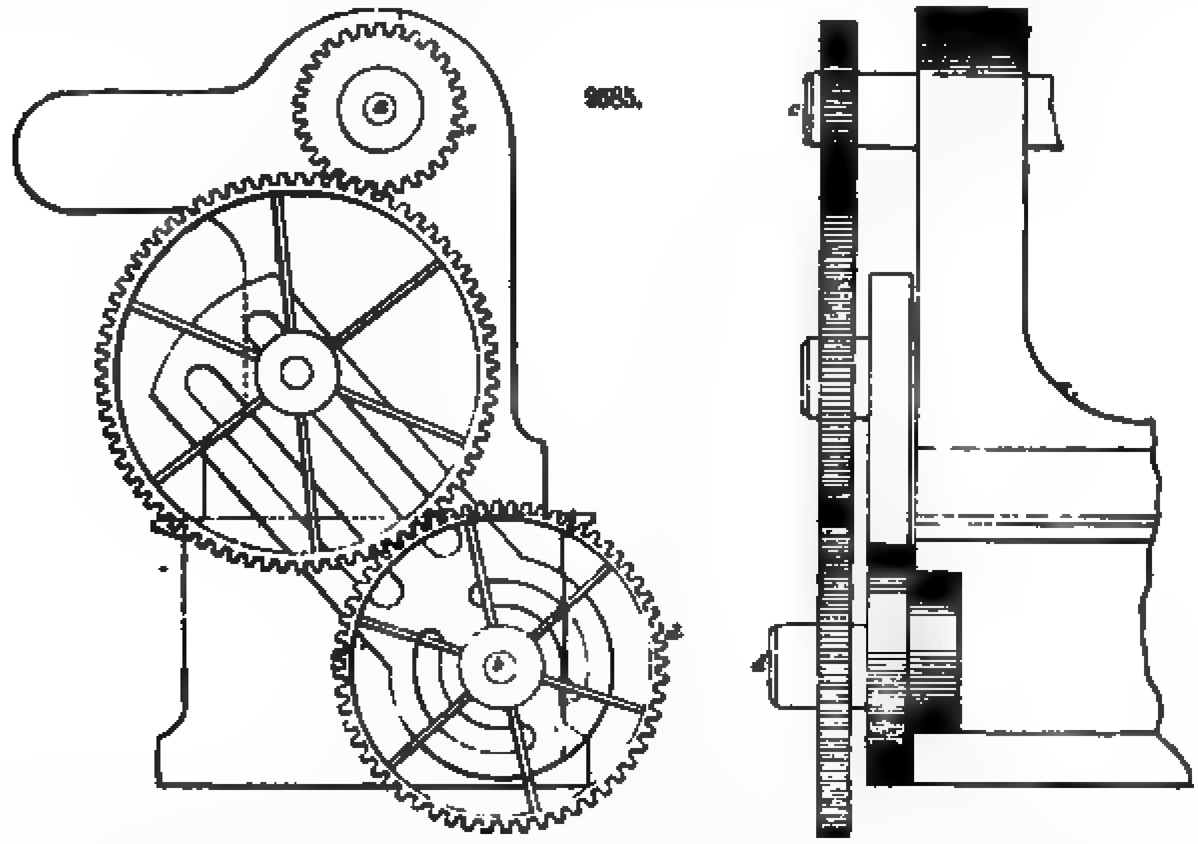
This rule may be used to advantage, because, when the feed-screw is employed for carrying plain feed-cuts, it usually requires one of the largest wheels upon it, because the tool-feed is usually finer than the threads ordinarily cut upon it. Hence, while it is almost always necessary to remove the driving-gear *c*, it is rarely requisite to change the feed-screw gear *d*, unless the thread to be cut is coarser than the pitch of the feed-screw, in which case the following rule may be used:

Divide the pitch of the thread to be cut by the pitch of the feed-screw, and the product will be the proportion required to exist between the number of teeth on the driving-gear and on the feed.

Example.—It is required to cut a thread of 8 pitch in a lathe whose pitch of feed-screw is 4: what number of teeth must the driving-gear and feed-screw gear respectively contain? *Ans.* $8 \div 4 = 2 =$ the proportion between the required gears. Hence, we select any two gears in which one contains

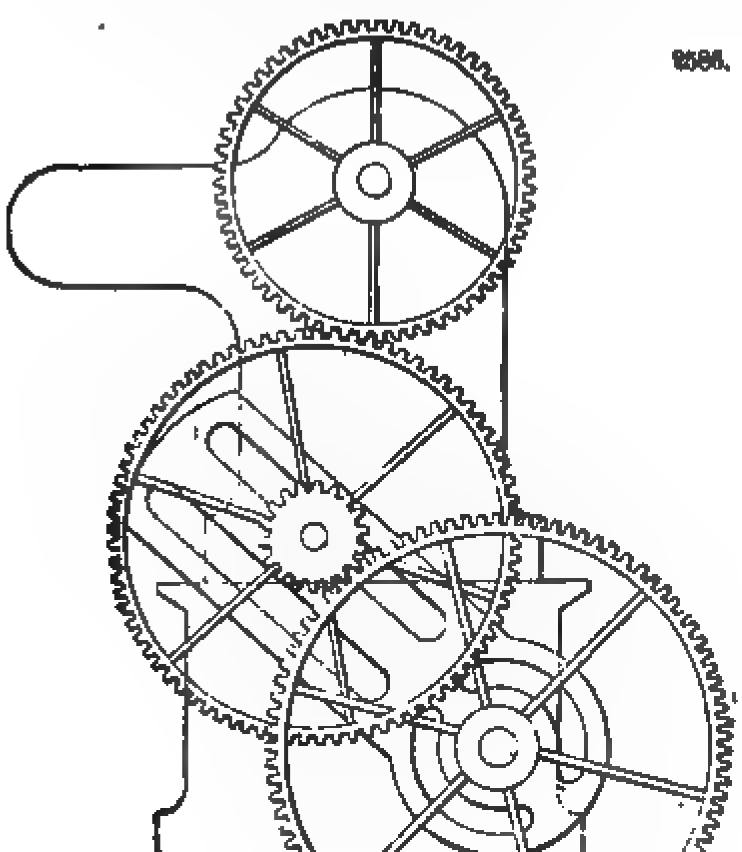
twice as many teeth as the other; and as the thread to be cut is coarser than the feed-screw, it is obvious that the smaller of the two must be placed on the feed-screw, and the larger on the cone or lathe-spindle.

The term *compound* or *double-geared*, as applied to the screw-cutting wheels of a lathe, means that between the driving-gear and the feed-screw gear there are two gears of different diameters, but



2585.

revolving on the same spindle or axis. The object of this arrangement, Fig. 2586, is to obtain a wider range of difference between the revolutions of the cone-spindle and the feed-screw than i possible in a single-geared lathe, and thus to allow of the cutting of threads of finer or coarser pitches. It is convenient when practicable to change one wheel only; and if it is determined to change the wheel upon the feed-screw, we may use the following rule:



2586.

Divide the pitch to be cut by the pitch of the feed-screw, and the product will be the proportional number. Then multiply the number of teeth on the lathe-mandrel gear by the number of teeth on the smallest gear of the compounded pair, and the product by the proportional number, and divide the last product by the number of teeth for the wheel on the feed-screw.

Suppose, for example, the gear on the lathe-mandrel contains 40 teeth running into the largest of the compounded gears, which contains 50 teeth, and that the small gear of the compounded pair contains 15 teeth: what wheel will be required for the feed-screw, its pitch being 2, and the thread requiring to be cut being 20?

Pitch required.		Pitch of feed-screw.		Proportional number.		Mandrel-gear teeth		Small compound gear.		Proportional number.		Large compound gear		
20	÷	2	=	10.	Then—	40	×	15	×	10	÷	50	=	120,

the number of teeth required upon the wheel for the feed-screw. In the above example, however, all the necessary wheels except one are given; and since it is often required to find the necessary sizes of two of the wheels, the following rule may be used:

Divide the number of threads to be cut by the pitch of the feed-screw, and multiply the quotient by the number of teeth on one of the driving-wheels, and the product by the number of teeth on the other driving-wheel; then any divisor that leaves no remainder to the last product is the number of teeth for one of the wheels driven, and the quotient is the number of teeth for the other wheel driven. (In this rule the term "wheel driven" means a wheel which has motion imparted to it, while its teeth do not drive or revolve any other wheel; hence the large wheel of the compounded pair is one of the wheels driven, while the wheel on the feed-screw is the other wheel driven.)

Example.—It is required to cut 20 threads to the inch, the pitch of the feed-screw being 2, one of the driving-wheels containing 40 teeth and the other 15.

Pitch required to be cut.		Pitch of feed-screw.		Teeth in one driving-wheel		Teeth in other driving-wheel.		
20	÷	2	×	40	×	15	=	6000.

Then, $6000 \div 50 = 120$; and hence one of the gears will require to contain 50 and the other 120 teeth.

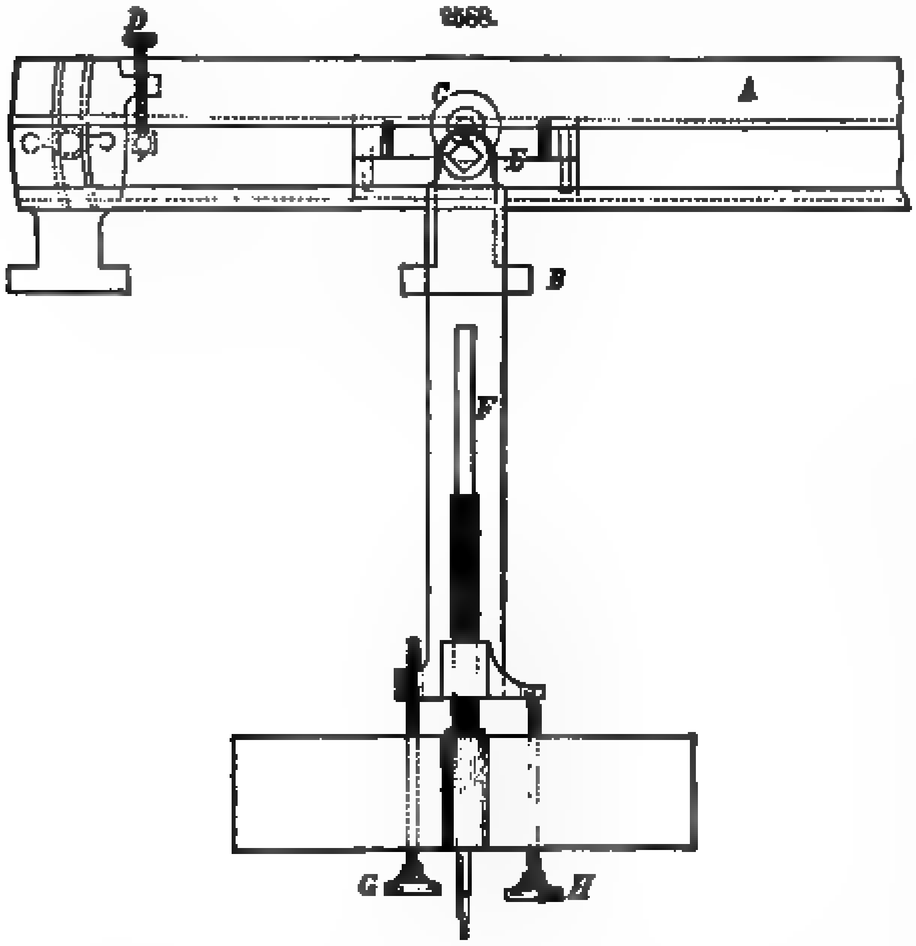
If we have not two of such wheels, we may divide by some other number instead of 50. Thus: $6000 \div 60 = 100$; and the wheels will require to have respectively 60 and 100 teeth.

If there are no wheels on the lathe, we proceed as follows:

Divide the pitch required by the pitch of the feed-screw; the quotient is the proportion between the revolutions of the first driving-gear and the feed-screw gear.

Example.—Required the gears to cut a pitch of 20, the feed-screw pitch being 4. Here $20 \div 4 = 5$; that is to say, the feed-screw must revolve 5 times as slowly as the first driving-gear. We now find two numbers which, multiplied together, make 5, as $2\frac{1}{2} \times 2 = 5$; hence one pair of wheels must be geared $2\frac{1}{2}$ to 1 and the other pair 2 to 1, the small wheel of each pair being used as drivers, because the thread required is finer than the feed-screw.

2588.



2589.

Weighted Engine-Lathe. — In Fig. 2587 is shown a back view of the Pratt & Whitney Company's (of Hartford, Conn.) weighted engine-lathe. In this class of lathe the lower part of the slide-rest, termed the carriage, is kept down to the guide V's by the weight shown suspended beneath the lathe-bed. This lathe is provided with Slate's patent taper-turning attachment. This is constructed as follows: At the back of the lathe-bed are three backets, shown at *E* in the plan view of the attachment in Fig. 2588. These brackets support an adjustable bar *A*. The centre bracket receives a pivot *C*, which the bar *A* swings, while the end brackets afford means of fixing the bar in its adjusted position. *D* is a thumb-screw for effecting the final adjust-

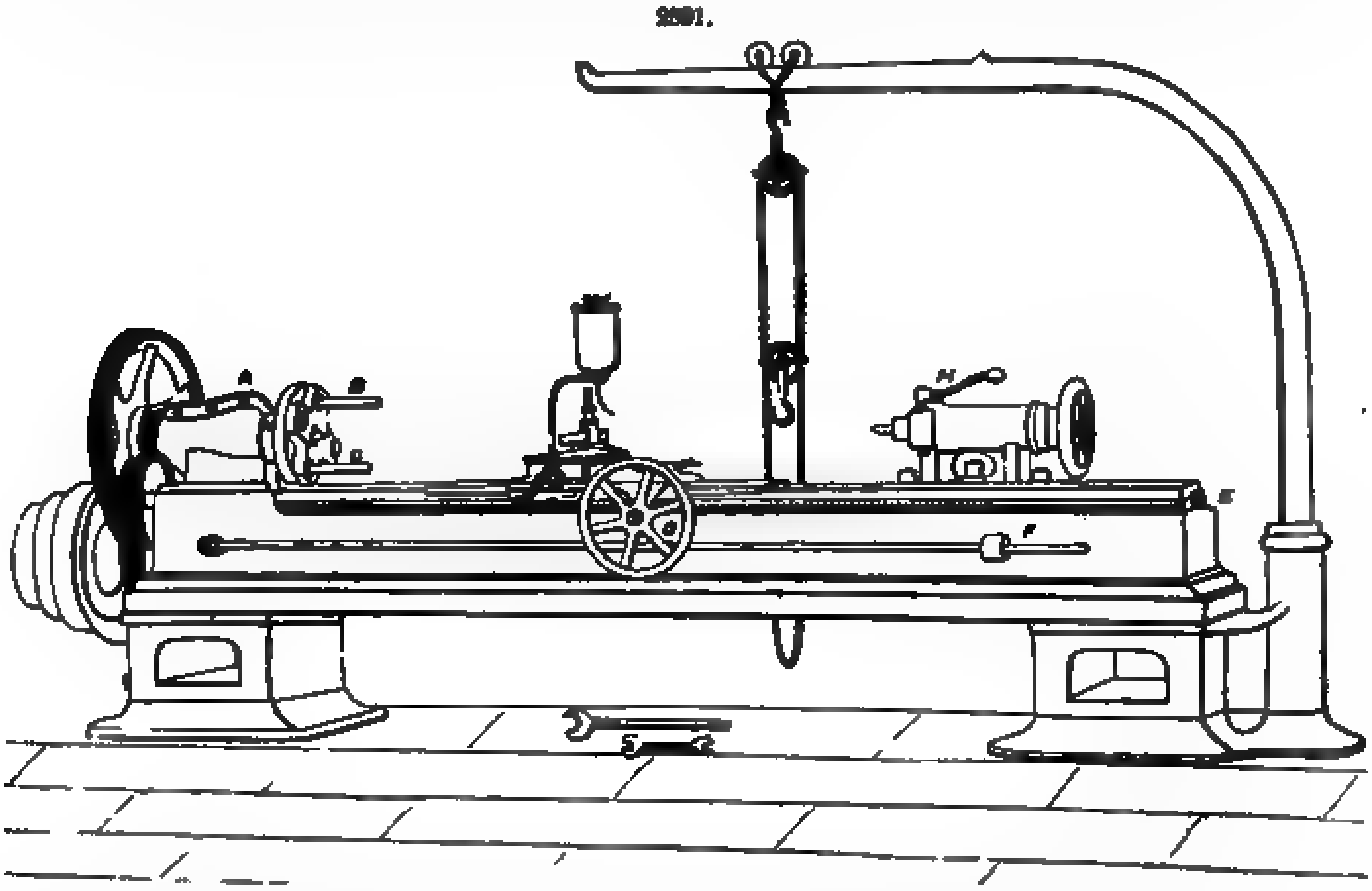
2590.

ment of *A* after it is placed as near as may be in position on the brackets. The bar *A* is provided with a longitudinal slot, into which the slide *E* traverses a close working fit; and to *E* is pivoted a bar *F*, which carries the nut for the cross-feed. The nut-bar *F* slides in a groove provided in the

lower part of the tool-carriage; hence, if A be placed at an angle to the ways of the lathe, the slide E imparts (as the carriage traverses) a transverse or cross-feed motion to the carriage, causing the tool to turn taper.

In one form of this lathe is a device for adjusting the fit of the tail-stock spindle without employing any parts save those necessary to the locking device. The manner of accomplishing this is shown in Fig. 2589, in which A represents the tail-stock spindle, and B the socket, with a clip shown at C for locking. D is the bolt or stud, having upon it the collar E. F is a washer, and G the handle. The operation is as follows: The stud D is screwed down until it closes the clip sufficiently to adjust

2591.



the socket a proper working fit to the spindle, after which the stud D remains in a fixed position. To lock the spindle, the handle G is used, thus forming a neat and effective device.

The Whitworth Duplex Lathe.—Fig. 2590 is a cross-sectional view (through the slide-rest and shears) of a Whitworth duplex lathe with compound slide-rest. There are two slide-rests operating upon the same carriage and moved by the same cross-feed screw, one being operated by a right-handed and the other by a left-handed screw, so that the two simultaneously approach or recede from the axial line of the lathe-centres when operated by the cross-feed screw. The turning tool for the front slide-rest is placed in the usual manner, while that for the back one is turned upside down,

2590.

the two tools, operating simultaneously, thus performing twice the quantity of work. A more important advantage is, however, that the strain due to the depth of cut is taken off at one traverse of the slide-rest, and, being thus divided, may be made equal on the two sides; and therefore the work is not sprung by that strain, and may be turned more true than it could with a single tool. Especially is this the case with long square-threaded screws or long spindles. The adjustment of the tools to their respective cuts is made by operating the respective upper slides of the slide-rests. It is usual, however, when the tools are first secured by the clamps, to set the front tool first and afterward adjust the rear one; and this is compulsory when the tools are not diametrically opposite, as in the case of screw-cutting; it being obvious that the tool which leads merely reduces the size of the work, while that which follows determines the finished diameter.

Lathe for Axle-turning.—The lathe shown in Fig. 2591 is constructed by the Putnam Machine Company for the especial purpose of turning car and locomotive axles. The bed-face contains two steps or ways, upon the upper of which the slide-rest or carriage travels, and upon the other the head- and tail-stock slide. The object of this arrangement is to keep the face upon which the carriage slides free from the turnings, and thus to avoid both friction and abrasion. The bearing for the running spindle is split at the top at *A*. Bolts pass through lugs provided on each side of the slot formed by the split, so that by screwing up the bolts the bearing is adjusted to fit the spindle. The bolts holding the driver to the face-plate pass through two slots in the driver, and the latter has two projecting driving-studs or pins, *B*, *C*, the object being to drive the work on two sides, and thus avoid the spring which is inherent to driving from one side. It is obvious that the driver, dog, or carrier placed upon the work must have two diametrically opposite projecting pieces and that the driver upon the face-plate of the lathe will adjust itself so as to come in contact equally with the lugs upon the driver or dog upon the work. The feed-screw of the lathe is driven by the gear shown, and passes along the middle of the way whereon the carriage slides, the nut at its end being shown at *E*. For moving the carriage by hand, the rack *F* is provided, to which a pinion operated by the hand-wheel *G* is geared. To prevent spring in the tail-stock, it is fastened to the bed-slide by the three bolts shown, while the tail-stock spindle is locked by a clip operated by the lever *H*. The rod *F* is for operating the feed, of which there are two speeds, one for roughing out and the other for finishing the work.

The Double Axle-turning Lathe.—In Fig. 2592 is shown a lathe designed to turn the two ends of an axle simultaneously. The driving-head is near the middle of the length of the lathe-bed, and is provided with a Clement's driver. The driving-spindle is hollow to permit the axle to pass through it. There are two slide-rests and two tail-stocks, as shown, so that the two ends of the work may be operated upon.

Gap Lathe.—An example of the gap lathe is given in Fig. 2593. By the use of the gap in the bed, a piece of work 48 inches in diameter and 26 inches in length may be turned; and by the face-plate on the back end of the spindle, a wheel 9 feet or more in diameter can be bored. The boring-bar is passed through the spindle, and is supported by a bush at one end, the other extremity being, as usual, carried to the rest. The dimensions of the machine here represented are 30-inch swing, 21 inches over the rest, and 10 feet 6 inches between centres.

Lathes for Turning Large and Heavy Work are provided with a bed resting directly upon the floor or foundation, without the intervention of supporting legs, necessary when shears are employed. In the Sellers lathes these beds are provided with three flat surfaces (instead of two) to support the

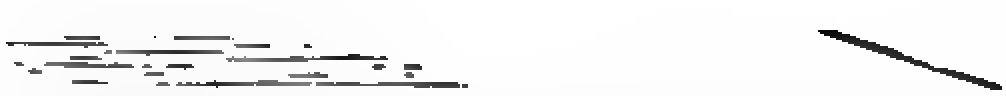
tail-stock and carriage, thus more effectually and rigidly supporting them and providing additional wearing area. In lathes of this class the work to be bored is often bolted to the carriage; hence

slots are provided in the carriage to receive such bolts, as shown in Fig. 2594. The head-stock and tail-stock of this lathe are bolted to the lathe-bed with four bolts each (two on each side), to prevent

them from springing. To obtain a very slow speed without the employment of many gear-wheels, the chuck-plate or face-plate is provided with internal gear-wheel teeth as shown, into which meshes a pinion driven by the back gear of the lathe. The radial slots shown upon the circumference of

the plate are to receive the heads of the bolts used to fasten work to the plate. In lathes of this class the cutting tool is held by two clamping plates, because one screw would not hold the tool with sufficient firmness.

Sellers's Improved Wheel-turning Lathe is represented in Fig. 2595. The heads of this lathe are unusually rigid, being "box-framed;" that is to say, the outer surface is a continuous piece, without any open panels or standards—a form which, in conjunction with the broad base of the head, gives great solidity. From the extra width of the bed the pressure of the cut always falls within the bed surface. The feed-motion for the slide-rest is obtained by an independent overhead rock-shaft. In this lathe there are two face-plates, the object being to enable the workman to operate each separately, so as to be boring on one while chucking work on the other, or to drive the work from both face-plates when necessary to avoid the spring due to the torsion produced by a heavy cut; while



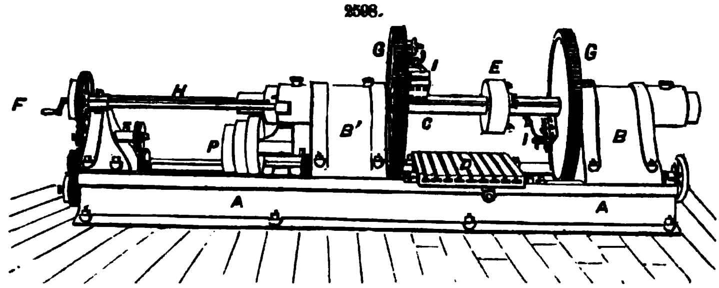
in wheel-turning both wheels may be operated upon simultaneously. The slide-rest may be operated by hand or by handles or pendants, which are connected to the screw by a ratchet motion, so that by an overhead motion the handles may be actuated vertically and reciprocally, thus making the slide-rests self-acting. The pendants are lifted by the overhead motion and fall of their own weight, the amount of movement and hence of feed being regulated at will.

Boring Lathes.—In Fig. 2596 is shown a combined machine of unusual dimensions manufactured by Messrs. Bement & Son of Philadelphia, which is adapted for boring cylinders of large dimensions, for drilling the bolt-holes in their flanges, and for surfacing the latter. The bed of the machine is 89 feet long, and it carries at one end a fixed standard *A*, which supports the gearing and boring bars. The latter is carried in the hollow spindle *D*, which slides through the spur-wheel *X*, and is driven through the stepped pulleys *T*. By means of the geared wheels *R* and the screw the bracket

carrying the whole of the boring motion can be raised or lowered. By a special set of gearing the bolt-holes can be drilled in the cylinder-flanges without removing the work. This is effected by means of the worm-wheel *Z*, which is turned by hand through the worm *A'*, and carries with it the frame in which are set the pinion *Y* gearing with *X*, the spur-wheel *F*, and the small pinion carrying the drill *E*. The drill thus can be brought to bear at any desired point of the flanges, and by causing the pinion on the spindle carrying the drill to turn around the spur-wheel *F*, it can be adapted to cylinders of different diameters. The form and arrangement of tables *K* to which the work is secured are shown in the perspective views and in the general plan. The standard *I* carries the bracket for holding the boring-bar bearing, as shown in the perspective view; a number of these bearings and bushes are provided with the machine to suit different-sized boring-bars. The height of these bearings can be adjusted by means of the screw and gearing, as shown. The standard *I* rests upon the central ribs of the frame, and is traversed by a screw. The third standard, shown in Fig. 2597, is used for surfacing work, and has a twofold motion imparted to it, transversely by the screw *M* and longitudinally by means of the traversing screw of the machine driven by a pulley. The bracket carrying the moving parts can likewise be raised and lowered by a vertical screw, and the cutting tool is mounted in the bracket *D*, and revolves around the spindle *C'*, driven by gearing as shown.

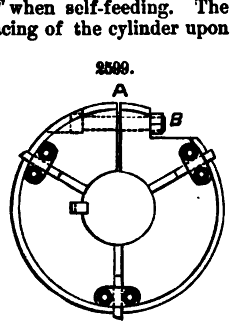
The Cylinder-boring Lathe shown in Fig. 2598 has attained a wide reputation for rapidity and excellence of performance in boring locomotive cylinders, for which purpose it was specially designed

2598.

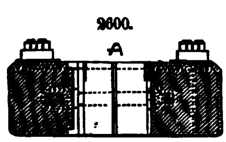


by William Sellers & Co. of Philadelphia. *A A* is the bed, carrying the heads *B B'*. Through these heads passes the boring-bar *C*, upon which is the head *E* for carrying the cutting tools. The cylinder is bolted to the stationary table *D*, and the revolving bar *C* traverses through the heads *B B'*, which afford it journal-bearing. *P* is the driving-pulley, the face-plates *G G* being driven through the medium of two pinions engaging with the gear-teeth upon the circumference of *G G*, and driven by a shaft operated by *P*. Motion from the heads to the bar is communicated through the medium of a fixed key or feather operating in a groove. The bar *C*, in feeding to the cut, passes through the bearings afforded it by *G G*, and is operated by means of the feed-screw *H*, which is revolved by the handle at *F* when operated by hand, and by the gear-wheels at *F* when self-feeding. The operation is as follows: The boring-bar is withdrawn to admit of the placing of the cylinder upon the table *D*, and then replaced in position, passing through the bore of the cylinder, and the latter is bolted to *D*; the revolving head *E*, carrying the cutting tools, operates upon the cylinder-bore. To face the ends of the cylinder, there are bolted to the face-plates *G G* two slide-rests *I*, which carry cutting tools. These slide-rests feed the tools to the cut in a line with the faces of the face-plates *G G*, and hence produce much truer work than is the case when the end faces are operated upon by cutters placed in the boring-head *E*, because in this latter case the cutter is fed to the cut in a line with the boring-bar, and the resistance due to the cutting duty is apt to spring the cutter back from its duty in the broader parts of the cut or the harder parts of the metal; while in case of local sponginess of the iron (or honeycombing, as it is commonly termed) the tool is (if fast to *E*) apt to cut deeper. Hence the employment of the rests *I I* is in every way preferable, whether they be operated while the boring duty is proceeding or not. At a trial of this machine made at the Centennial Exposition, it performed the remarkable feat of boring and facing a locomotive cylinder of 17 inches diameter of bore and 24 inches long, and of turning up the faces at each end of the same, in 3 hours and 40 minutes, which is about one-third the time usually occupied upon such work. The boring-head is made to suit the size of the work, and is held securely to the bar by means of a clip, as shown in Figs. 2599 and 2600, the slit *A* springing slightly open to release the head from the bar and to facilitate its instant removal. The tightening upon the bar is accomplished by simply tightening the nut *B*. The head contains three fixed cutters, as shown in Fig. 2599, and is provided with a key in addition to the clip device referred to. J. R.

2599.



2600.



LATHE, WOOD-WORKING. The general arrangement of a wood-turning lathe, which may be driven either by the operator or by horse, is shown in Fig. 2601, which represents the Victor wood-turning lathe No. 2, made by Messrs. J. A. Fay & Co. This is designed especially for all varieties of wood-turning in cabinet, sash and door, and pattern shops, etc. The end of the spindle rests in a

2601.

2600.

hardened steel screw of large diameter, which receives all the pressure of the tail-stock, and has adequate arrangements for oiling and taking up the wear.

Fig. 2602 represents a wood-turning lathe of which the frame is in a continuous piece, no legs being required. This arrangement tends to prevent the vibration to which fast-running machines are subject, owing to want of balance either in the working parts of the mechanism or in the work itself. The rest is pivoted to the frame so as to be adjustable to suit the form and size of the work, and is supported at the outer end by a stay or leg.

Lathe for Turning Irregular Forms.—The lathe for turning irregular forms contains the generic idea of all machines for duplicating shapes by using a model in conjunction with a blank, the outline of the model guiding the cutting tool to produce a duplicate from the blank. This ingenious device may be said to have wrought a complete revolution in that branch of wood-working to which it appertains. Originally applied to turning lasts, it has since been employed to shape the most difficult forms, such as gun-stocks and axe-handles. The method of making gun-stocks, and the irregular lathe used for the purpose, will be found under Fire-Arms, Manufacture of. The lathes used for axe-handles in the West are intended merely to rough out the material. The blanks or pieces to be turned are placed between points and rotate slowly in contact with stiff circular saws, which cut away the wood in a spiral course like a planing block, and leave a true but rough outline for the finished handles. From 300 to 500 pieces can be turned in 10 hours on a lathe of this kind, and one boy can attend two machines.

The originator of the lathe for irregular forms was Thomas Blanchard of Philadelphia, who patented the device September 6, 1819. If a pattern be placed in a lathe, and the material to be turned placed with its axis of rotation similar to that of the pattern, and if a guide pressing on the pattern directs a wheel with cutters to operate on the rough material over a surface like the pattern as guided, a perfect representation of the pattern will be produced on what was the rough material, simply by the cutters chipping away all the rough material outside of the axis of direction—in other words, all the wood on the rough material outside of the pattern. This is the principle upon which this machine is constructed.

Fig. 2603 represents an improved modern form of this lathe, constructed by Messrs. Richards, London, & Kelley of Philadelphia. It will be noticed that the material to be operated upon is mounted upon a pivoted swing-frame, the cutters moving in a straight line, and the motion to produce the crooked or elliptic form of the work is given to the pieces to be turned, and not to the cutters. The carriage on which the cutters are placed is mounted on wheels, so as to be easily run back after finishing a piece, and is made very heavy to resist any jar from the cutters, which are driven at a velocity of 8,000 feet a minute at the perimeter. The feed-movement is positive, by means of the screw shown on the front, and is regulated by change-pulleys, as the irregularity of the work or other conditions may render necessary. The model or pattern is in the same plane with the pieces to be shaped, and in this feature there is a considerable gain over the older forms of the Blanchard lathe, where the patterns employed were not duplicates of the article to be produced.

2604.

Universal Lathe.—Fig. 2604, Nos. 1 to 19, represents an improved universal lathe designed by Messrs. Koch & Müller of Prussia. It is furnished with two mandrels, W and W', the latter revolving in the former. As will be seen from the engraving, the cone-pulley R, receiving the first motion, drives the external mandrel W. The toothed wheels Z, Z', Z'', and Z''' form the usual lathe-gearing, and both the toothed wheels $Z Z'$ drive a shaft w, to the end of which is fixed a toothed wheel Z' gearing with the toothed wheel Z''' attached to the internal mandrel W'. By changing the toothed wheels Z'' and Z''' in size, any proportion of the number of revolutions of the internal

mandrel W' and of the external mandrel may be produced. A disk E fixed to the internal mandrel may be eccentrically adjusted on it; on this disk moves the face-plate on which the objects to be turned are fixed; a driver M attached to the external mandrel causes this face-plate to rotate.

The mode of operation in this lathe is easily to be understood. As shown in the engraving, the toothed wheel Z'' is of half the size of the wheel Z'; therefore the eccentric disk E and the mandrel W' turn twice—that is, the object to be shaped is twice approached to the chisel and twice withdrawn from it, and yet makes one revolution only with the face-plate by means of the driver. The shape of the object to be worked will be that shown in No. 4 or 6, according to the eccentricity of the position of the disk E on the shaft W'. In changing the wheels Z' and Z'' with those of threefold, fourfold, or higher velocity ratios, the figures 5, 8, 10, etc., will be produced. If the head of the screw S, which connects the disk E with the shaft W', and prevents at the same time the face-plate P from sliding away, has been conveniently shaped, it may be used as a common centre for turning shafts in the usual manner. If shafts are to be turned, a second head-stock instead of the puppet is to be applied to the lathe; but in this case the head-stock is provided with one mandrel only, arranged in the manner shown in W' without the face-plate P. The head V of the external mandrel W is purposed to bear a wheel not shown in the drawing, by means of which the self-motion of the slide-rest is produced in the usual manner.

It is claimed for this lathe that in comparison to all other known oval lathes it has the great advantage that the position of the chisel is always more favorable. For instance, the positions of the chisel when cutting an ellipse may be seen from No. 14, the dotted lines showing the position of the chisel in the common pattern-lathe, and the continuous lines showing the position of the same in the new lathe. Another difference between this and other lathes is that the chisel cuts much more slowly at b than at a. In Nos. 12 and 13 a locomotive axle-box and a common journal-box are shown. By means of this lathe both the blocks as well as the corresponding bushes may be turned on the face-plate without any fitting of these parts by hand. If the disk E of the lathe before the head of the shaft W' is adjusted by means of an endless screw in the same manner as a slide-rest is put in motion, the bushes may be finished on the face-plate.

The shaft W' in the second head-stock being prevented from rotating, the figure turned to the other side becomes gradually a circle. If in this arrangement the centre of the shaft W' is withdrawn from the chisel to a distance half the eccentricity of the disk E with reference to the shaft W' of the first head-stock, the diameter of the circle to be produced is as long as the longest diameter of the figure turned to this side. The forms produced in this way are particularly useful in the manufacture of reamers and screw-taps. In Nos. 16 and 17 cross-sections of reamers are shown as made till now, and as they may be made by means of this lathe. In making a reamer—No. 16—at first the cavities a are cut in the round bar shown in dotted lines, and afterward the parts b are shaped in the form shown by means of a file by hand. This latter part of the work must be executed with the greatest care, and cannot be done but by the most clever workman if the reamer shall satisfy its purpose. One awkward stroke of the file applied to the edge pushes it behind one part of the surface and thereby prevents the tool from cutting. In making by means of the lathe the triangular cross-section of the tool (the dotted circle is only made in order to show better the triangular form), it is only necessary to cut away the parts a, and the file is entirely dispensed with. The operation of milling by means of this lathe may be executed also by increasing the eccentricity of the disk E, and by withdrawing the chisel. If the triangular cross-section of the reamer as shown in the drawing becomes by and by a circle, it fits more and more perfectly the hole to be made, and after it has passed through it the hole is exactly circular. As to the screw-taps, Nos. 18 and 19, the same remark as to the reamer may be made; but the screw-tap made by means of the lathe has the advantage that not only the point of the thread b, but the basis also, is behind the cutting edge s, which is not the case in screw-taps made otherwise.

If the number of teeth of the wheels Z' and Z'' are not in the precise proportion from 1 : 2, 1 : 3, 1 : 4, and the figures to be produced run in screw lines around the shaft, and if the number of revolutions of the shaft W' of both the head-stocks is different, the figures of the cross-sections at both sides of the shaft to be turned are different, and become by and by the same. If the wheels Z and Z' be different in size, and the wheels Z' and Z'' elliptic, other and remarkable figures are produced. Hereby it may be seen that it is very easy to produce many new, useful, and complicated forms, of advantage in architecture, cabinet-making, the manufacture of umbrellas, walking-sticks, etc. The driver turning on a fixed point, and the face-plate on a pivot, the centre of which moves in a circle, the circular velocity of the face-plate is not perfectly uniform, and the figures are symmetrical with reference only to a line passing the centre. The irregularity of the figures is only remarkable if the eccentricity in comparison with the length of the driver be very great. If the number of revolutions of both the mandrels be in the proportions of 1 : 2, figures are produced which, according to the angle formed by the driver and the eccentric pointing straight upward, are egg-shaped and become gradually oval, one half being narrower than the other. If, instead of connecting the pivot of the face-plate with the pivot of the driver by means of a movable crank, the pivot of the driver be made to press against a projecting rim of the face-plate, it would slide to and fro on this rim double the eccentricity for each revolution of the face-plate. The figures thus produced are like those described already. If the said rim is not rectilinear and radial, it is possible, though in narrow limits only, to turn any forms. In increasing the number of drivers and rims of the face-plate, the circular velocity can be made uniform to any degree, even with short drivers.

LATHE-CHUCKS are devices for holding work to be operated upon by tools, or for holding tools to operate upon work. One of the simplest forms of chuck is shown in Fig. 2605, and is termed a *chuck-plate* or *face-plate*. The mode of attaching work to this device is shown in Fig. 2606, which represents a crank chucked, that is, fastened to the face-plate. B is the crank; a, a, and c are plates of iron secured by bolts which attach B to the face-plate. When, as in the figure, the weight of the

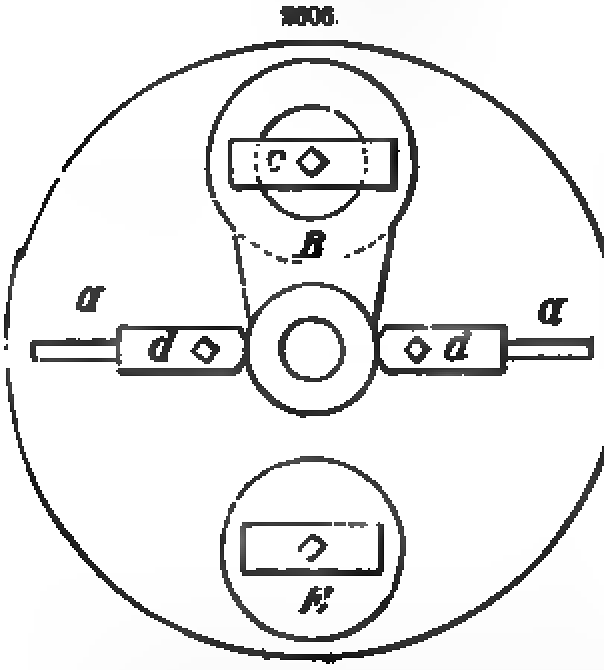
work is greater on one side of the plate than on the other, a counterpoise or balance-weight *E* is employed.

Angle-Plate.—The angle-plate is an attachment for the chuck-plate of a lathe. It consists of a casting *A*, Fig. 2607, having two true flat surfaces at a right angle one to the other, so that when one of these surfaces is bolted to the chuck-plate the other shall stand at a right angle to the surface of the latter. It is shown chucking a pipe-bend, and it is obvious that, the two flanges of the bend being respectively held by the bolts and plates at *P*, the flanges when turned will stand at a true right angle one to the other. To facilitate adjusting the angle-plate to any required position about the chuck-plate, numerous holes are provided in the latter, as shown at *B B*. *E* is a balance-weight adjusted to counterbalance the weight of the work and of the angle-plate.

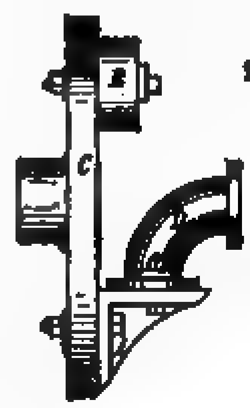
2605.

Attachment of Small Chucks.—To facilitate the attachment of small chucks to the lathe-spindle, the threads on the spindle are sometimes cut off on opposite sides for a distance a little over one-quarter of the circumference on each side, as shown in Fig. 2608. The thread on the bore of the chuck must be cut away in a similar manner, so that, by holding the chuck with its remaining thread opposite to the blank spaces on the spindle, the chuck may be pushed nearly home, and less than a quarter turn will bring it home. In cutting the sections of thread away, however, it is necessary first to properly clean the thread of the chuck and of the spindle, and then screw the chuck fairly home, and divide the radial faces of both spindle and chuck into

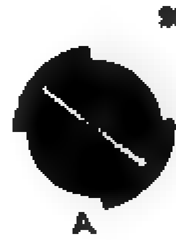
2606.



2607



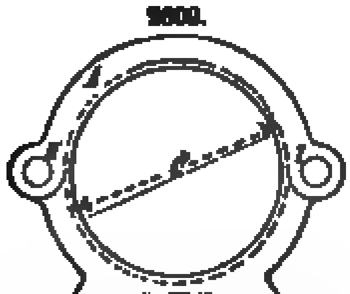
2608



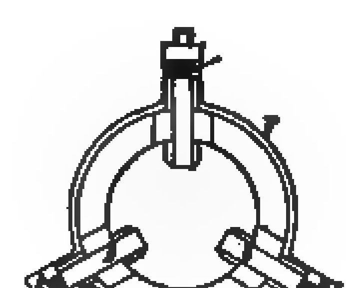
four equal divisions, marking two diametrically opposite divisions on the chuck and the corresponding ones on the spindle, as those to be cut away. This will insure that the threads will be in the right position to have good contact when the chuck is home.

Steady-Rest for Lathe-Work.—The steady-rest is an appliance wherewith to hold the end of a piece of work, so that it may be operated upon without the use of the back or dead centre, or to form a journal-bearing to a piece so slight as to be liable to deflect from the pressure of the cut. It consists

2609.



2610.



2611.

of a frame capable of adjustment along and attachment to the lathe-bed, and containing pieces or jaws that can be adjusted to touch the work and afford it a journal-bearing at a part which has been previously turned true.

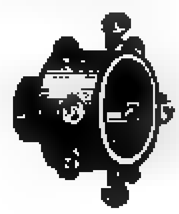
* In Figs. 2609 and 2610 is shown a steady-rest. The frame *A* is bolted to the lathe-shears *B*, *B*, and the bore *C* bored out true by a boring-bar placed between the lathe-centres, and is recessed as shown by the dotted circle, in the same manner as is an ordinary engine eccentric. The part *F* shown in Fig. 2610 is turned on its outer edge so as to fit and revolve freely in the bore *C*. The work to be supported or steadied is firmly grasped by the jaws *D*, *D*, *D*, which are set up by the screws *E*, *E*, *E* respectively, so that as it revolves the part *F* revolves with it. This device obviates

* By Professor J. E. Sweet, in the *Polytechnic Review*.

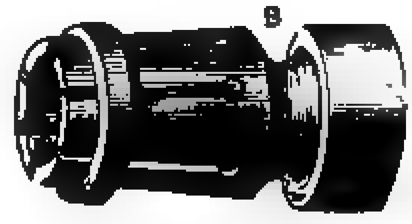
the necessity of clamping the driven end of the work to the face-plate of the lathe to prevent it from moving laterally away from the live centre, as it is apt to do unless so clamped in the ordinary steady-rest, especially when the cut traverses from the live centre toward the dead one. The top half of the frame A is pivoted at $H\ I$, so that the wear of F may be taken up and lost motion prevented.

2612.

2613.



2614.



2615.

The Dog-Chuck or Jaw-Chuck, shown in Fig. 2611, is provided with dogs or jaws operating radially and independently in slots, by means of screws passing through the jaws, which are secured in the slots by nuts and washers, as shown in Fig. 2612. The defect of this class of chuck is that, if from wear or other cause the dog fits loosely to the plate, it cants over when forced to the work. If

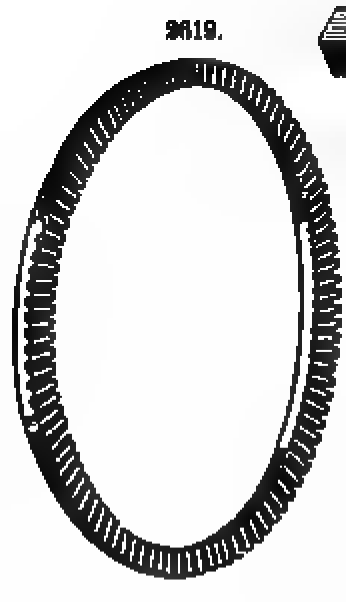
2616. 2617 2618.

E

2622.

88

2619.



2620.

2623.

the face E of the jaw grips the work, the jaw cants as shown; but if the work is gripped at F, the jaw will cant in the opposite direction.

A *bell-chuck* is shown in Fig. 2613, in which the work is gripped in the bore of the chuck by means of the 8 screws shown.

In all these chucks the work has to be set central with the chuck by manipulating the screws indi

vidually. To avoid this difficulty, various constructions have been resorted to. Thus, in Fig. 2614 is shown a *spring-cut chuck* of wood, which is closed centrally upon cylindrical work by driving the ring over the chuck.

Another of this class of chucks is that shown in Fig. 2615, which represents a *scroll chuck*. *A*, *B*, *C* are three pieces which together form the main body of the chuck. Inclosed between *A* and *B* is the ring *D*, which can revolve independently. In the face of the chuck are three radial grooves, each of which has two feathers projecting from its sides into the body of the groove. Sliding freely along these grooves and feathers are three jaws. On the radial face of the ring *D* a spiral of about 3½ revolutions is cut, corresponding to a square thread. Counterparts of the spiral are provided on the internal edge of each of the jaws, which when in position are in contact with the face of the ring *D*; so that by revolving this ring while the body of the chuck is at rest, the three jaws are made simultaneously to advance or recede from the centre of the chuck with an equal velocity. To revolve this ring, the holes shown at *H H* are provided, a cylindrical-ended lever fitting therein, while to hold the body of the chuck stationary the holes *I* are provided.

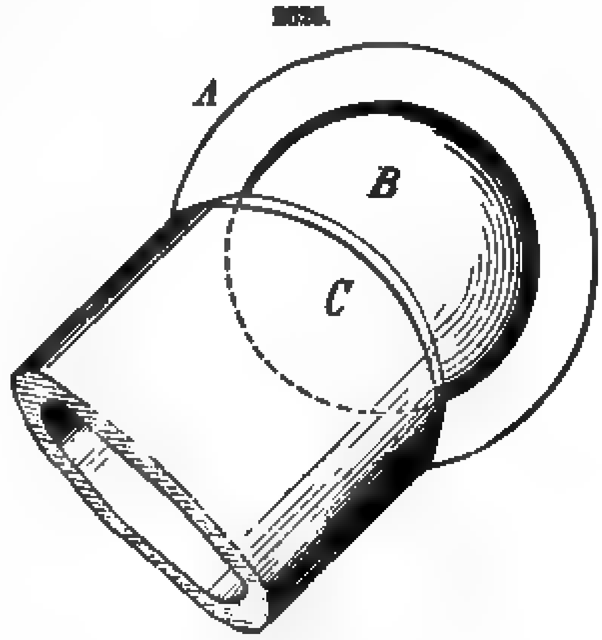
Another form of *self-centering chuck* is shown in Fig. 2616. The scroll *C*, which is in fact a helix or coil, is in one piece with *B*, which attaches to the mandrel; and as the threads of this scroll gear with the notches in the three dies, the latter will of course advance to the centre, or recede from it, when the scroll is made to revolve. The part *E* screws on as an outer cap upon the base-plate. When such chucks are employed to hold heavy work, the strain upon them is great, and it is necessary that the parts be substantial and have ample wearing surface provided, and that the cuttings and grit be excluded from the working parts.

The continued truth of the chuck is largely dependent upon keeping the wear as small as possible, and thus preventing lost motion in the working parts. The wear due those parts, if kept properly

2614. 2615.

lubricated and free from the fine lathe-cuttings, is very small indeed compared to that which takes place if not kept free from the cuttings. In the construction of the *Horton lathe-chuck*, shown in detail in Figs. 2617 to 2621, the above considerations are provided for in the following manner: The jaws are operated to and from the centre by means of screws attached to each jaw, the motion of any one screw (and consequently jaw) being communicated uniformly to the others by means of a pinion operating in a circular wrought-iron rack, which is much more durable than if made of cast iron. The chuck is constructed in two parts, one (the back) of which contains the circular rack, and the other (the front half) the jaws and the screws with their accompanying pinions. To provide against the entrance of dirt or cuttings to the rack and pinions, there is inside, as well as outside, a raised flange or ring, so that when the two halves of the chuck are fitted together, the entrance of those substances is practically prevented.

2616.



Frost's Variety Self-Centering Chuck is represented in Figs. 2622 and 2623. It consists of an outer casing or roller, which receives the screw *B*. Said screw has a square recess in its head, and is turned by an ordinary key. The lower end of the screw bears on the jaw *C*. The under face of this jaw is V-shaped. In each of its sides is a recess to accommodate the bent springs, which are attached to the jaws *D* and *E*. These jaws bear flat against the case, and by their inclined sides bear also against the V of jaw *C*. They are provided with projections at *F*. From Fig. 2623 it will be evident that if the jaw *C* is pressed down, its inclined faces, acting on the upper inclined sides of jaws *D* and *E*, will force these jaws together, and, as contact becomes closer, the projections *F* on the latter will interlock. The square-shanked tool will then be held on two sides of the V of the jaw *C*, and on the other sides by the proximate parts of jaws *D* and *E*, and the tool will be the more tightly held as the screw *B* is turned down. When the screw is relaxed and the tool removed, the springs on jaws *D* and *E* will expand, and the jaws will thus

be carried back to their former places. If a tapered tool be inserted, the moving jaws D and E will assume an angular position, holding the shank tightly as before.

Vinton's Chuck is represented in Figs. 2624 and 2625. The collar A which encircles the spindle

2627. 2628. 2629.

2630. 2631. 2632.

2633. 2634. 2635.

2636. 2637. 2638.

2639. 2640. 2641.

B

D E

B C

2642. 2643. 2644.

has formed on its outer face a bevel-gear wheel B. C is the rear portion of the shell of the chuck, inclosing the forward part of the collar A. Also on the collar A are a washer D, which rests against

the shell C, and a nut E, which travels on a thread formed on the collar. As it is necessary to turn the entire shell in order to move the jaws, the use of the nut just described is to jam the part C and the enlarged portion of the collar A tightly together, and so rigidly hold the jaws in any position in which they may be adjusted. Fig. 2624 represents the outer face of the chuck with the jaws and their working mechanism. Within the chuck, each jaw has attached to it a screw E. This enters a bevel-wheel F. As the jaws are incapable of any but radial motion, it follows that, when the chuck is rotated bodily and the bevel-wheels engage on the motionless gear-wheel B, the effect of the rotation of said bevel-wheels is to cause the jaws to travel toward or from the centre of the chuck-face; and it will be further clear that this motion must be simultaneous in all the jaws. As the outer portion of the chuck is rigidly secured to the shell C by screws, of course when that shell is jammed, as already stated, by the nut E, it becomes impossible to turn the chuck bodily; and hence the bevel-wheels cannot be rotated around the main gear-wheel, and consequently the position of the jaws cannot be altered. Devices are also provided by which any jaw may be accurately adjusted from the outside, so as to secure a firm grasp upon the tool.

Ball-Turning Chuck.—In the ordinary practice of lathe-turning, it sometimes becomes necessary to improvise a chuck for work of such a nature that none of the standard forms of chuck will hold. As an example of this kind, we have the ball-turning chuck shown in Fig. 2626. It consists of a block of soft metal, such as a mixture of lead and tin, in which is turned a cavity to receive the ball. A is the chuck, B the ball, and C the cutting tool. This chuck drives the work by friction.

The Eccentric Chuck is employed mainly for ornamental turning work. * By its use the turner is enabled to bring other centres than that upon which the object was turned into the axial line, as, for instance, the centre of a crank-pin, or that of the seconds-dial upon the face of a watch. Figs. 2627 to 2644 are all specimens of what an eccentric chuck alone, with a fixed cutter in the slide-rest, is calculated to effect. Fig. 2627 may represent a watch-face with seconds dial. Fig. 2628 often goes by the name of a Turkish cap. The circumferences of the smaller circles all pass through the centre of the main circle, their diameters being exactly half the diameter of the latter. If this were intended for real ornamentation, a large number of circles would be thus cut, instead of the six here shown. In Fig. 2629 the diameters of the smaller circles are more than half that of the larger, so that they extend beyond the centre of the latter. The centres of the small circles are points, it will be noted, upon the circumference of a circle described round the main centre, and concentric with it, as is the case with Figs. 2628 and 2630, the latter being like Fig. 2629, but with a greater number of circles. In Figs. 2631 and 2632 the centres of the secondary circles are upon the circumference of the main circle, and they are also of equal radius with it, but here only half of each secondary circle appears. Fig. 2639 is a circle of which A is the centre, and the line $B\,E\,C\,D$ is called its circumference or boundary line. $D\,E$ and $B\,C$ are diameters (the word signifies cross measure, or measure across), and all lines passing through the centre of any circle, and meeting the circumference on opposite sides of it, are all alike diameters. Half a diameter, as $A\,B$ or $C\,A$ in Fig. 2640, is a radius. The word radius, of which radii is the plural, signifies a spoke of a wheel. It is evident that as each radius begins at the centre and is bounded at the opposite end by the circumference, all the radii in any circle are equal, as are all the diameters.

Fig. 2645 is a front view, Fig. 2646 a side view, Fig. 2647 a top view, and Fig. 2648 a part section, showing the channel for an eccentric chuck. The part M to receive the mandrel, and the base-plate

2645.

2647

2648.

2646.

$A\,A$, are in one casting. The slide is drawn to and fro by means of the screw, similar to a slide-rest. This screw contains 10 threads to the inch, and has a divided head and pointer to indicate the amount of its revolution. Upon the face of the slide is a click-wheel in one piece with the nose P, which is the exact counterpart of that on the mandrel, and carries the same chucks. It revolves

* From "Turning for Amateurs."

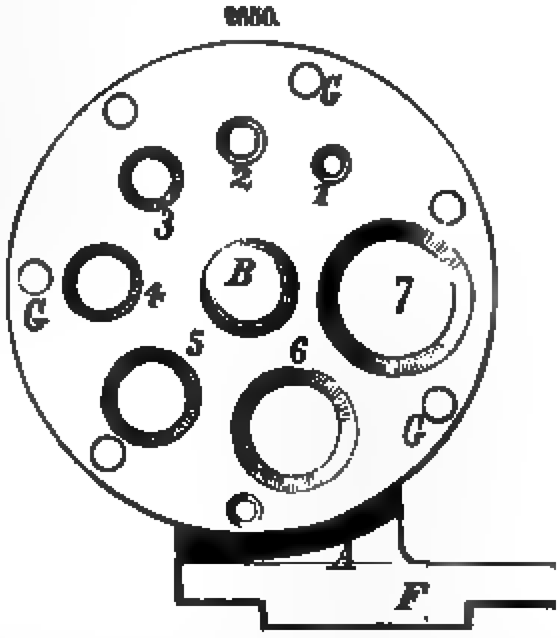
upon a stout conical centre-pin firmly attached to the centre of the sliding plate, and is secured by a screw. *E* is a ratchet kept against the click-wheel by the spring *D*. The front of the dividing-wheel is commonly divided into 96 parts, of which each sixth division is numbered, and also into a second circle of 100 divisions. In point of fact, as the screws are all made with 10 threads to the inch, and both slide-rest and eccentric chuck are thrown out one-tenth at each turn of these screws, it would seem more desirable to arrange the division of the click-wheel, and also at least one circle upon the face-plate of the mandrel, so that it could be divided decimally. This is indeed sometimes done with a tangent screw and worm-wheel. The head of the screw being divided into tenths and half-tenths, and the screw being of 10 pitch, one turn of the screw will move the slide one-tenth, five turns five-tenths, and so on; and one division (of the tenths) will represent one-hundredth as the amount of the movement of the slide. For practical purposes, this movement of the slide is called its "eccentricity," and would be thus written in describing the above degrees: "eccentricity $\frac{1}{10}$, or $\frac{5}{10}$, or $\frac{1}{100}$." On the other hand, "radius" signifies the number of divisions of the slide-rest screw by which the tool is thrown out of centre (in the centre of the lathe-mandrel). These terms are of constant use in describing any particular patterns made by this chuck. Comparatively numerous as such patterns are, they are comprised within certain easily-defined limits.

2649.

Chucking in Cement.—The arrangement of a metal disk in the lathe, so that it can be turned on its face and upon its edge, cannot well be accomplished by means of chucks; for this purpose recourse is frequently had to cement. To chuck work with cement, apply a small portion of it to a face-plate devoted especially to this purpose; heat the plate so that the cement will cover the greater portion of its surface. The plate may be allowed to cool. Whenever it is desirable to chuck a metallic disk, it is heated and placed against the cement on the face-plate, and allowed to remain until the cement begins to stiffen, when a tool having a right-angled notch is applied to the edge of the disk, as shown in Fig. 2649, the lathe being rotated until, by the compound action of the tool-pressure and the rotary motion, the disk becomes perfectly true. To remove the work from a cement chuck, it must be warmed by means of a lamp or otherwise. Most of the cement adhering to the work may be wiped off after heating it; whatever remains may be removed with a little turpentine.

The Cone-Plate.—For chucking shafts and other similar work in the lathe (to bore holes in the ends of the shafts, etc.), the cone-plate shown in Figs. 2650 and 2651 is employed. *A* is a standard, fitting in the shears of the lathe at *E*, and holding the circular plate *C* by means of the bolt *B*, which should be made to just clamp the plate tightly when the nut is screwed tight. The plate contains a series of conical holes, 1, 2, 3, etc. (shown in section at *D*, Fig. 2651). The object of coning the pin *B*, where it carries the plate *C*, is that the latter shall be made to a good working fit and have no play. The operation is to place the shaft in the lathe, one end being provided with a driver, dog, or carrier, and placed on the running or live centre of the lathe; and the other end, to be operated upon, being placed in such one of the conical holes of the plate *C* as is of suitable size, the distance of the standard *A* from the lathe-centre is to be adjusted so that the work will revolve in the coned hole with about as much friction as it would have were it placed between both the lathe-centres. Thus the conical hole will take the place of the dead centre of the lathe, leaving the end of the shaft free to be operated on. *F F* are holes to bolt the standard *A* to the lathe shears or bed; and *G*, *G*, etc., are taper holes to receive the pin *G* shown in Fig. 2651. The object of these holes and pin is to adjust the conical holes so that they will stand dead true with the lathe-centres; for if they stood otherwise, the holes would not be bored straight in the work. In Fig. 2650, hole No. 7 is shown in position to operate, the pin *G* locking the plate *C* in that position. In setting the work, the nut on the pin *B* should be eased back just sufficiently to allow the plate *C* to revolve by hand; the work should then be put into position, and the pin *G* put into place; the standard *A* should then be adjusted to its distance from the live lathe-centre, and bolted to the lathe-bed; and finally, the nut on the pin *B* should be screwed up tight, when the work will be held true, and the cone-plate prevented from

2650.

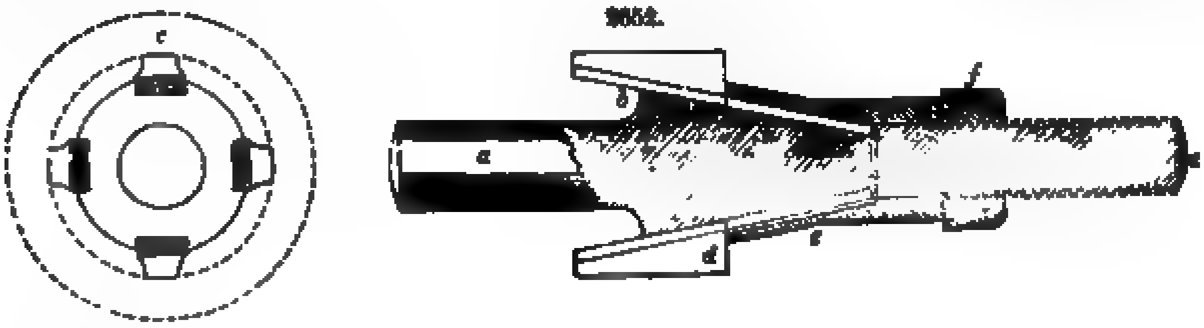


2651.

springing. Care must be taken to supply the conical holes in which the work revolves with a liberal quantity of oil; otherwise they will be apt to abrade.

Mandrels.—These are cylindrical pieces of soft or hardened steel, used to hold work by being driven into a hole or bore. They are turned very true and carefully centred and centre-drilled when used for lathe-work. After the hardening process, during which they are subject to warping, they are ground by an emery-wheel to true them up. They should be left a trifle larger than the required finished size, to allow for the reduction in diameter due to the grinding process. The method of grinding is as follows: The mandrel is revolved between the lathe-centres in the usual

2652.



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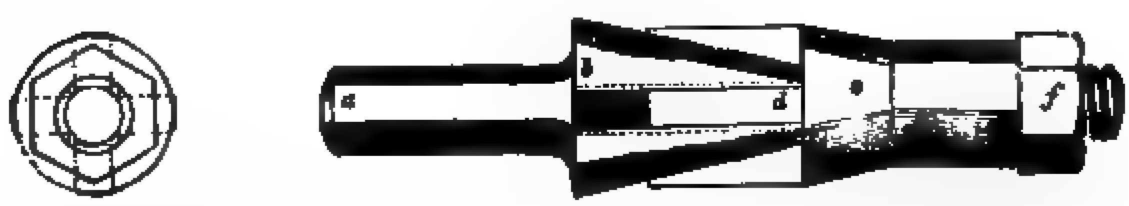


way; then there is held upon the lathe-carriage an emery-wheel revolved by independent overhead gear in an opposite direction from that in which the lathe runs. A cut is put on in the usual way by the cross-feed screw of the lathe, and carried along by the usual feed-motion.

To avoid the necessity of having a mandrel for every size of hole, what are termed expanding mandrels are sometimes employed. Such a mandrel is shown in Figs. 2652 and 2653. *a* is the stock or body of the mandrel; *b* is a cone solid thereon, and containing four dovetailed taper slots, in which are fitted with a sliding fit four pieces of metal, *d*. *e* is a washer, and *f* a nut. As the nut is screwed up, the pieces *d* are forced up the inclined grooves, expanding to suit the diameter of the

2654.

2656.

2655.

hole, and jamming against the bore of the work, holding it by the friction due to the pressure. Expanding mandrels are rarely used for fine lathe-work, because of their liability to get out of true.

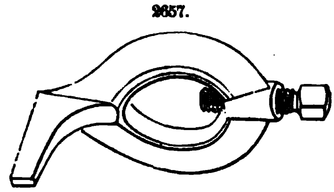
Another form of this tool, termed a cone-mandrel, is shown in Fig. 2654, which is a bar or spindle *a*, having on it, either solid or a tight fit, and abutting against a collar as shown, the cone *b*. *c* is another cone, an easy sliding fit on the spindle, which may be screwed along the latter by the nut *B*. In tightening it is screwed from the end *D* toward the cone *b*. *F* represents a piece of tube shown in section, and being held by the pressure placed upon it by the two cones in consequence of *B* being screwed up. It is obvious that this tool will hold any work having a bore within the limits of the

diameter of the cones at their two ends. If the tube held, however, is of soft metal or very thin, the pressure of the cones is apt to expand the bore at the extreme ends.

Nagle's Expanding Mandrel, Figs. 2655 and 2656, is either threaded to receive a nut for facing up, or left plain to receive a pulley-coupling, or anything that may require turning. Fig. 2655 is a perspective view of the mandrel, with a nut on ready for facing, and Fig. 2656 is a longitudinal section. The arbor *B* is bored through from end to end, the hole for nearly the whole of its length being slightly tapering, as seen plainly in the section. From the open end of the taper the mandrel is sawed lengthwise into three equal parts, the slots extending nearly the whole length. A plug *A* fits the hole in the mandrel, but its straight part is turned up farther than the taper in the mandrel extends, so as to permit it to be driven in, thus expanding it slightly and holding very firmly whatever may be on it. A slight tap on the other end of the plug releases it, and a small nut *C* prevents the plug from falling out. J. R.

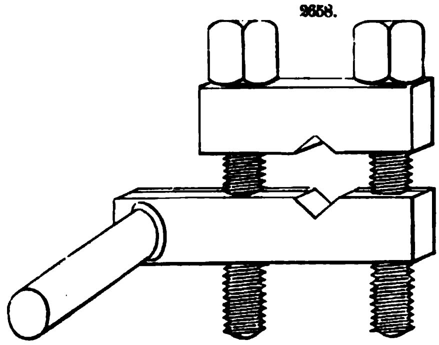
LATHE-DOG. In Fig. 2657 is shown an ordinary lathe-dog or carrier. It is fastened upon the end of cylindrical work to drive the same. When used upon finished work, a piece of copper should be placed between the end of the screw and the work to prevent damage to the latter. In cases where very heavy cuts are to be taken, two of these carriers may be used. In such case they should first be screwed up, not too tightly, and after starting the lathe and putting on a cut to bring them both to a bearing against the driving-pin, the lathe may be stopped and both the carriers screwed up tightly. For driving square shafts in the lathe, the clamp shown in Fig. 2658 is employed. The jaws should be screwed down even so as to bear evenly on the work, and not to bend the jaws of the clamp.

2657.



For heavy work and for turning long shafts, Clement's driver, Fig. 2659, has been widely adopted. It differs from one form of the ordinary drivers in having two driving-pins instead of one, and in having them fixed in an outer plate instead of in that which is attached to the mandrel. This outer plate is capable of sliding laterally for a short distance, thus accommodating itself to any inequality in the width of the opposite ends of the carrier; by which means each of the pins is made to transmit an equal share of the driving power on each side of the carrier, which prevents the pressure from springing the work out of straight.

2658.



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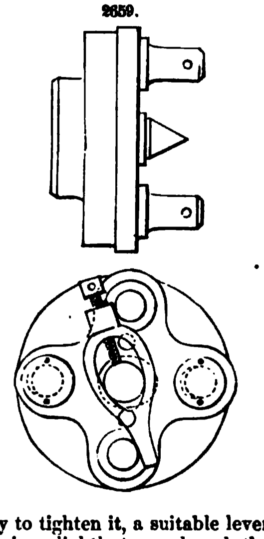

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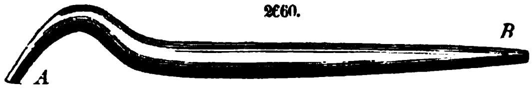
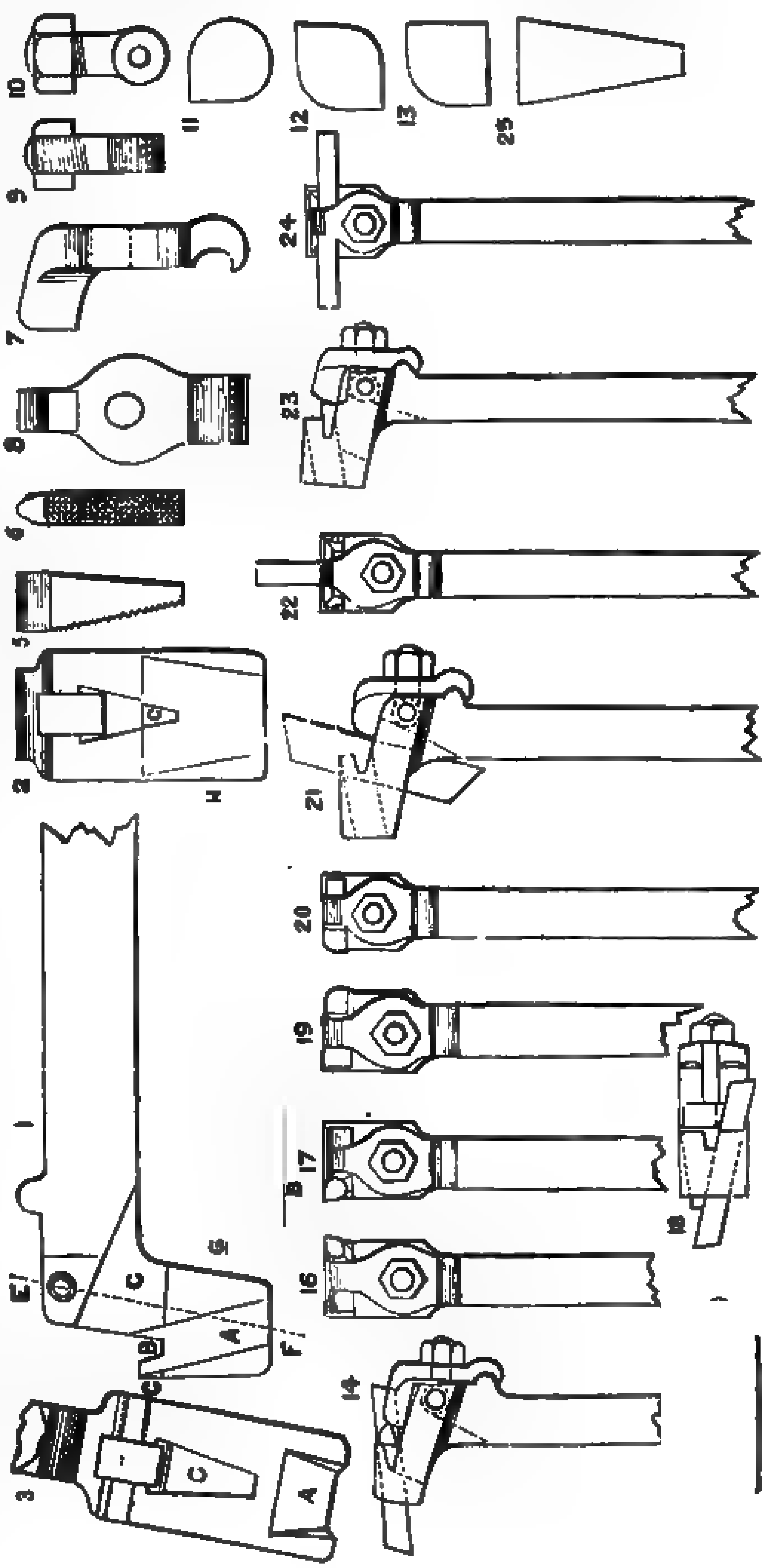


When the screw-head of a lathe-dog is provided with a hole whereby to tighten it, a suitable lever is required. Such a tool is shown in Fig. 2660, the ends *A* and *B* being slightly tapered, and the bend at *C* being to facilitate the movement of the lever in confined places, where only a quarter turn or less can be given the screw-head at one movement, and the hole may come into such a position that the straight end *B* cannot be used. J. R.

LATHE-TOOL HOLDERS. Devices for holding tools in the lathe. In Fig. 2661 are shown an important series of appliances designed by Messrs. New & Mathews, and adapted for holding securely, in a rectangular tapered slot, a right-hand or left-hand cutting tool at suitable and fixed cutting angles. The tools are fastened firmly by a serrated wedge and clamps, held down by a swivel-bolt and nut. The devices also serve for holding, in suitable tapered slots, a straight tool and a cross tool cutting on either side at right angles. These tools are secured by clamps held down by swivel-bolt and nut. It has been proposed to use in these tool-holders special sections of steel which can be formed into uniform angular or round-nosed tools for right- or left-hand cutting. From the same uniform bar of steel tools can be cut in suitable lengths, and then, without being forged, ground to a proper cutting angle for the several purposes required. Further, the novel shape of these special sections, when placed in the new holder, gives a positive and fixed angle for cutting. No. 1 is a side elevation of tool-holder in section (on line *G H*, No. 4). *A* is a rectangular tapered

slot; *B* is a tapered slot at right angles to the lengthway of the holder; *C* is a tapered slot parallel with the lengthway of the holder. No. 2 is an elevation of the tool-holder. No. 3 is an elevation in section (on line *E F*, 1), showing the tapered slot *C*. No. 4 is a plan of tool-holder, showing the rectangular tapered slot *A*, and tapered slots *B*, *B*, and *C*. No. 5 is a front elevation of serrated wedge, and No. 6 is a side elevation of it. No. 9 is a front elevation of swivel-bolt and nut, and No. 10 is a side elevation of the same. Nos. 11, 12, and 13 are the special sections of steel particularly adapted for the tool-holder, to be held in the rectangular tapered slot *A*, 1. No. 14 is a side elevation of the right-hand tool for cutting out corners, and No. 18 is a front elevation of it. No. 19 is a plan of right-hand round-nosed tool, and No. 22 a front elevation of it. No. 23 is a side elevation of a cross tool, and No. 24 a plan of it. The tapered slots *B* and *C*, in No. 1, are adapted for holding cutters severed from a bar of steel of uniform section, but thicker upon one edge than the other, as shown in section in 25. Nos. 11, 12, 13, and 25 are full size, as shown; the others are half size.



2661

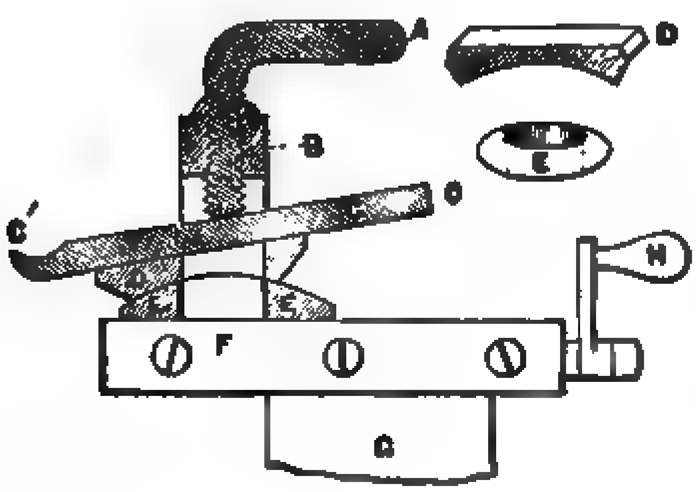
Lathe-Tool Height-adjusting Device.—In Fig. 2662 is shown Professor J. E. Sweet's device for adjusting the height of lathe-tools to the work. *A* is the clamp-screw; *B*, section of tool-post; *C*, tool; *D*, bolster of steel, blue temper, with roughened lower edge or face, fitting to *E*, a spherical washer, which rests on *F*, the upper slide of slide-rest. The point *C'* of tool may vary, as desired, nearly an inch in height. In this device the cuttings are not apt to lodge on the piece *E E*, as is liable to occur when the washer *E E* is made the concave and *D* the convex piece.

Baville's Lathe-Tool Holder is represented in Figs. 2663 to 2666. Fig. 2663 is a longitudinal section, Fig. 2664 a horizontal section, Fig. 2665 a front elevation, and Fig. 2666 a vertical section. It consists of two main parts, *A* and *B*, fitted together and fastened by screws *a*, so as to present a cylindrical head, in the interior of which is placed the movable nut-shaped piece *C*, which holds the cutter

D; this "nut," fitted exactly to the receptacle formed to hold it, in the interior of the parts *A* and *B*, is of a spherical shape in the middle, with a conical part above and below, terminating in a cylindrical tenon forming two pivots, on which it can make a rotary movement of half a circle. The circumference of this sphere is cut with a thread *c*, gearing into a worm *b*, the journals of which are made square at the ends to receive a handle *d*, by the aid of which it can be turned. In order to hold the tool firmly, this nut *C* is pierced by a slightly angular opening (shown in Fig. 2666) corresponding to the section *D* of the cutter, which fits in very accurately, leaving room however for the insertion of the wedge-shaped piece *e*, which is screwed down tightly by the screw *E*. This short description will give some idea of the valuable service a tool can offer which, like this, can act at will perpendicularly or parallel to the axis of the lathe, or in any of the intermediate oblique positions; further, by means of its simple form and mobility, it can be employed in working on certain

2663. 2665.

2662.



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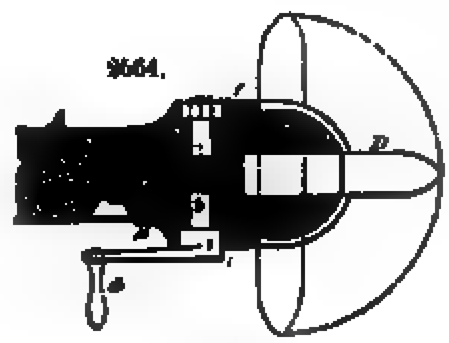
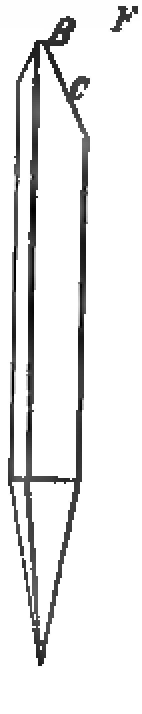


2666.

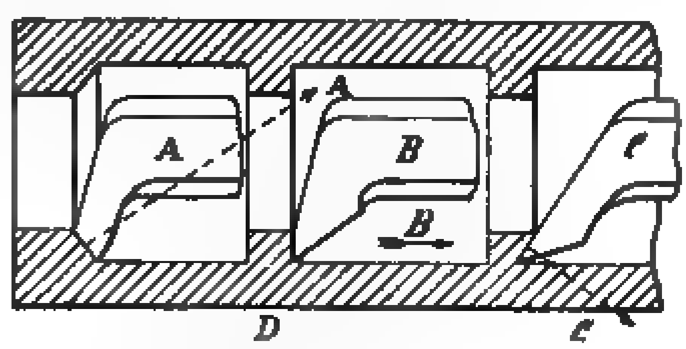
interiors, ordinarily requiring a tool forged to a special shape. The cutting tool being placed in the tool-holder, and fixed in the best position to suit the work, it is indispensable that it should be absolutely fixed in that position; a brake is therefore applied to the axis of the worm *b*, in such a manner as to insure the rigidity of the nut *C* in any desired position; this brake consists of a wedge *f*, acted upon by means of the screw *G*, so as to press it, by the interposition of the plate *g* (Fig. 2663), on the two half journals *h*, embracing the axis of the screw half its circumference. Only part of the means employed for fixing these two parts together is indicated by the screw *a*, which holds together the two jaws *A* and *B*, joined very accurately one upon the other, one of which contains two tenons which go into the grooves *i* made in the other, and which are shown in Figs. 2663 and 2664. This screw alone would not suffice; so the two parts of the head of the tool-holder are fixed together, above and below the nut, by means of two rings *j*, fitted in like hoops. J. R.

LATHE-TOOLS, BORING AND DRILLING. Boring Tools.—For boring in the lathe, the tools shown in Fig. 2667 are employed. Those shown at *A* and *B*, having their cutting edges at *C* and *D*,

2667.



2668.



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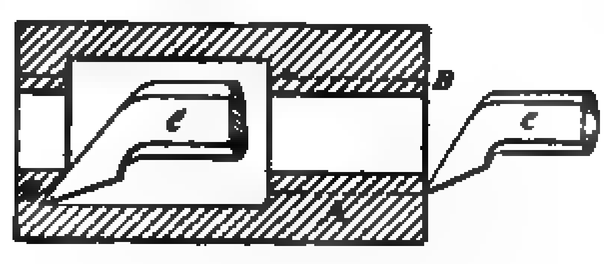
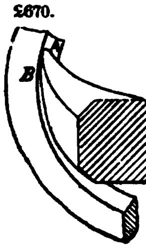


are therefore right- and left-hand tools. When, however, the hole is too small to admit of those tools being used, that shown at *E* may be employed, its cutting edge being on its end, at *F*. The temper of all these tools should be drawn to a light-brown color. Scraping tools of this kind may

be made of any curve or sweep, or have a cutting edge made of any necessary shape to form a moulding or irregular form; but the width of the cutting edge must not exceed about an inch.

The pressure on the cutting edge of a tool acts in two directions, the one vertical, the other lateral. The downward pressure remains at all times the same; the lateral pressure varies according to the direction of the plane of the cutting edge of the tool to the line or direction in which the tool travels, the general direction of the pressure being at a right angle to the general direction of the plane of the cutting edge. For example, the lateral pressure, and hence the spring, of the various tools shown in Fig. 2668, will be in each case in the direction denoted by the dotted lines. *D* is a section of a piece of metal requiring the three inside collars to be cut out; *A*, *B*, and *C* are variously shaped boring tools, from which it will be seen that *A* would leave the cut in proportion as it suffered from spring, which would increase as the tool-edge became dull, and that the cut forms a wedge, tending to force the tool toward the centre of the work. *B* would neither spring into nor away from the cut, but would simply require more power to feed it as the edge became dulled; while *C* would have a tendency to run into the cut in proportion as it springs, and as the tool-edge became dull, it would force the tool-point deeper and deeper into the cut until something gave way. Now, in addition to this consideration of spring, we have the relative keenness of the tools, it being obvious at a glance that (independent of any top rake or lip) *C* is the keenest and *A* the least keen tool; and since wrought iron requires the keenest, cast iron a medium, and brass the least keen tool, it follows that we may accept, as a rule, *C* for wrought iron, *B* for cast iron, and *A* for brass work. To this rule there are, however, variations to be made to suit exceptional cases, such for instance as when a hole terminates in solid metal and has a flat bottom, in which case the tool *B* (slightly modified toward the form of tool *C*) must be employed. Or suppose a hole in cast iron to be, as is often the case, very hard at and near the surface of the metal. Tool *A* would commence cutting the hard surface, and, becoming dull, would spring away from the cut in spite of all that could be done to prevent it; while tool *B* would commence cutting both the hard and the soft metal together, the cutting edge wearing rapidly away where it came into contact with the hard surface of the metal; and these conditions would in both cases continue during the whole operation of boring, rendering it difficult and tardy. But if the tool *C* were employed, the point of the tool would commence cutting the soft part of the metal first, and would undermine the hard surface, and (from the pressure) break it instead of cutting it away, as shown in Fig. 2669, in which *A* represents a piece of metal to be bored, the bore being hard to the depth of the dotted lines *B*. *C* is the tool shown as it would begin to cut, and also as it would work while in full operation. After the hard surface is removed, tool *B*, in Fig. 2668, may be employed to finish the boring, the point being ground a little more rounded. The objection to tool *C* for employment upon cast iron and brass is that, in consequence of its excessive keenness, it is liable to jar or chatter. Tool *B* may be given top rake and employed to cut out a square corner, or it may, if not ground too keen, be used upon brass; but it is liable in such case to jar or chatter, unless the top face is ground away. Here, then, we come to the consideration of top rake, that is, the shape of the top face of the tool. This in a boring tool lessens the strain due to severing the metal; by presenting a keener cutting edge, it lessens the tendency to lateral spring, and increases that to vertical spring, and is beneficial in all cases in which it can be employed. Upon wrought iron and steel it is indispensable; upon cast iron it may be employed to a limited degree; and upon brass it is inadmissible by reason of its causing the tool either to jar or chatter. In Figs. 2670 and 2671, *B* represents a section of the work; Fig. 2670 represents a boring tool with top rake, for wrought iron, and Fig. 2671 a tool without top rake, for brass work, which may be also used for cast iron when the tool stands a long way out from the tool-post or clamp, under which circumstances it is liable to

2670.



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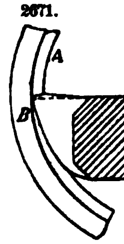

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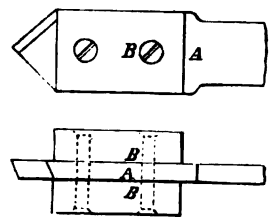


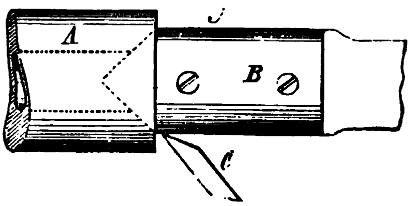
jar or chatter. A tool for use on wrought iron should have the same amount of top rake, no matter how far it stands out from the tool-post; whereas one for use on cast iron or brass requires to be the less keen the farther it stands out from the tool-post. To take a very smooth cut on brass work, the top face of the tool shown in Fig. 2671 must be ground off, as denoted by the dotted line.

Drilling Tools.—To enlarge holes and true them out, the flat drill shown in Fig. 2672 is employed. It is an ordinary drill made out of flat steel, having pieces of hard wood fastened to the cutting end, *A* being the steel, and *B B* the pieces of wood, held on by screws. When the drill has entered the hole far enough to make it of the diameter of the drill, the pieces of wood enter and fit the hole, steadying the drill and tending to keep it true. It is necessary, however, to true out the hole at the outer end before inserting the drill; for if the drill enters out of true it will get worse as the work proceeds. The drill is fed to its duty by the back lathe-centre, placed in the centre upon which the drill has been turned up. The pieces of wood should be affixed before the drill is turned up, and so trued up with the drill, which should then be lightly draw-filed on the sides; and the cutting end, having the necessary rake filed upon it, should be tempered to a straw color, the pieces of wood being of course, temporarily removed. For use on conical holes the sides must be made of the requisite

shape, and the cutting speed in that case reduced (in consequence of the broad cutting surface) to about 10 ft. per minute. (This speed will also serve in boring conical holes with a half-round bit.) Such a drill is an excellent tool for ordinary work, such as pulleys, etc., because it will perform its duty very rapidly and maintain its standard size, and it requires but little skill in handling. It is more applicable, however, to cast iron than to any other metal. After the outer end of the hole has been turned true, and of the required size to receive the drill, and when the latter is inserted for operation, it is an excellent plan to fasten a piece of metal, such as a lathe-tool, into the tool-post, and adjust the rest so that the end of the tool has light contact with the drill, so as to steady it. The lathe should be started and the tool-end wound in until, the drill being true, the tool-end just touches it, as in Fig. 2673.

The half-round bit, Fig. 2674, is used to drill or bore holes of moderate size requiring to be very true and deep. The cutting edge A is made by backing off the end, as denoted by the space between the lower end of the tool and the dotted line B, and performing its duty along the radius, as denoted by the dotted line in the end and top views. It is made as follows: Forge it as near to the required size as possible, and from square steel if it is obtainable, leaving stuff sufficient to true it up. In order to turn the cutting end between the lathe-centres, so as to have the centre at the shank end quite true with the turned part, it must be forged at the end to more than half the diameter, so as to leave sufficient metal to receive the centre-hole and countersink whereon to turn it. The shank end

2673.



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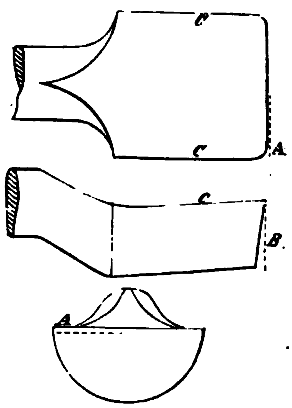

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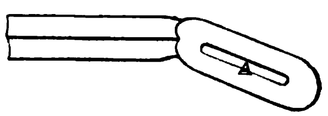

should be forged square, and should, when centre-drilled, have a deep countersink. The cutting end must be turned true and smooth, being quite parallel, if to be used for parallel holes, and of the desired taper for taper holes. For parallel holes all the cutting is performed by the end face A; but in taper holes, the side edges C of the top face also perform cutting duty, and hence the necessity of having the turned end of an exact thickness of half a diameter. After turning, and before removing it from the lathe, a tool having a point should be fastened in the slide-rest, its point being made to bear lightly against the turned face, close to one of the edges C; and the rest should then be passed along so that the point will describe a line true with the centre upon which the tool has been turned, which line will form a guide for filing the top face down to make the tool of the required thickness of one half of its diameter. The edge A should be perfectly square with the side edges C C. The circumference of the turned part should have the turning marks effaced with a very smooth file, by draw-filing the work lengthwise, care being taken to remove an even quantity all over. The rake of the tool, as denoted at the dotted line B, should not be greater in proportion than is there shown. This tool should be tempered to a straw color and employed at a cutting speed of about 15 ft. per minute, and fed at a coarse feed by hand. For use on parallel holes no part should be ground save the end face; whereas in the case of taper ones, the top face may be ground, taking as little off as will answer the purpose.

The drill-holder, Fig. 2675, is fastened in the tool-post of a lathe to guide a drill, the drill passing through the slot A. J. R.

LATHE-TOOLS, HAND-TURNING. I. For Wood.—*The Gouge.*—For roughing out work, the turning gouge, shown in Fig. 2676, is used. In grinding this gouge, it is necessary to lower the back hand when grinding at and toward the outside corners, so that the cutting edges may be formed, by the junction of two faces, at as acute an angle as those forming the cutting edge in the centre of the width of the tool. It is always the custom to reduce the work in the lathe to nearly the required form by this tool, the finishing tools being (with one exception) simply scraping tools, and not, properly speaking, cutting tools; hence it is evidently unadvisable to leave much for them to take off. The manner of holding the gouge is shown in Fig. 2677. One hand grasps the handle near the end, while the other grasps the gouge near the cutting point, that is to say, as near as the hand-rest will permit. It is sometimes, however, necessary to slightly vary the manner of holding by passing the forefinger of one hand around the hand-rest while the gouge is confined between the thumb and forefinger, thus gripping the gouge-end to the rest. This is advisable when turning a piece of work that is not completely round, as, for instance, tipping off the teeth of a gear-wheel, in which case gripping the gouge to the hand-rest will steady it and prevent it from digging into the work. The gouge is shown in

Fig. 2677 to be cutting from right to left; it will, however, cut equally well if used from left to right, in which case the position of the hands must be reversed, the left hand gripping the gouge near the cutting edge. In either case, however, the gouge is not held level, but is tilted to one side, the lower side being the cutting one; otherwise the tool would rip into the work.

In Fig. 2678, the section *A* shows the tilt of the tool when cutting from left to right, and *B* from

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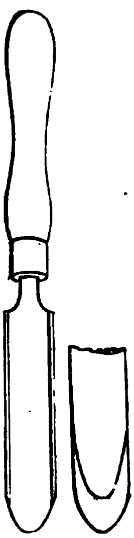

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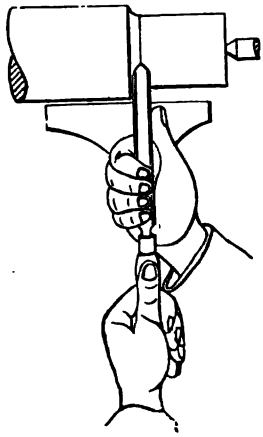

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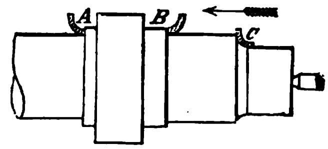

right to left. The reasons for this are as follows: The face of the gouge, on its hollow side and near the cutting edge, receives the strain which is necessary to curl the shaving, that is to say, which is necessary to force it out of the straight line. But if we were to place the gouge in the position shown at *C*, the whole of this strain would be placed upon the gouge, tending to force it forward and into the cut, as denoted by the direction of the arrow; and as a consequence, the gouge would run forward and dig into the work, in spite of all endeavors to prevent it. When, however, the gouge is held in the positions relative to its line of travel to its cut shown at *A* and *B*, there is but little tendency for it to run forward, and it can be fed easily to its cut. In addition to its use as a roughing tool, the gouge makes a very efficient finishing tool for hollows, though it is not often employed as such by pattern-makers. In this case, however, great care must be taken in controlling its position to the work, as shown in Fig. 2678.

Chisels and Finishing Tools.—For finishing plain work, we have the tool shown in Fig. 2679, which is the exception noted previously as being at the same time a finishing and a cutting tool. It is called a skew-chisel, because its cutting edge is ground at an angle or askew to the centre line of its length. Furthermore, it is beveled at the cutting end on both sides (as shown in the edge view), being ground very keen. It is employed for finishing straight or parallel surfaces, and for dressing down the ends or the sides of a collar or shoulder. When used for finishing straight or parallel surfaces, it performs its cutting in the centre of the length of its cutting edge only, as shown at *A* in Fig. 2680, and is held in the position relative to the work shown in Fig. 2679. When nicely sharpened it leaves a polish, unlike other finishing tools. But with these advantages, it has the drawback of a propensity to tear into the work, which can be overcome only by learning from practice how to handle the

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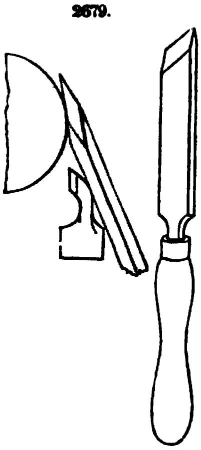

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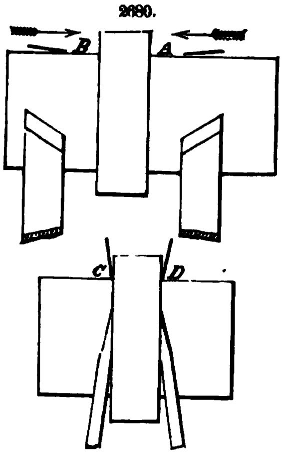

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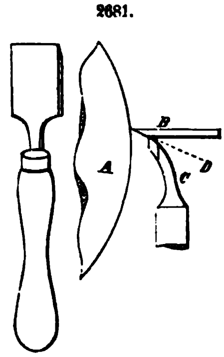

tool with dexterity. It must be held almost flat; and yet, if it should get quite flat, the cutting edge would act along its whole length, and the pressure of the cut would be sufficient to force the tool-edge deeper into the work than is intended. The face of the chisel nearest to the face of the work being operated upon stands almost parallel, with just sufficient tilt of the tool to let the cutting

edge meet the work in advance of the inside face of the tool; or in other words, the amount of the tilt should be about that of the intended depth of the cut, so that, when the cutting edge of the tool has entered the wood to the requisite depth, the flat face will bear against the work and form a guide to the cutting edge. The corner of the chisel which is not cutting must be kept clear of the work. Fig. 2680 will convey the idea, the arrows showing the direction in which the chisel is, in each case, supposed to be traveling. The short lines *A* and *B*, under the arrows, and those touching the collar at *C* and *D*, show the tilt or incline of the chisel to the work. In turning the circumference, the obtuse corner of the chisel is the cutting one, while in turning down a side face it is the acute angle. Most pattern-makers, however, do not often use the skew-chisel for finishing straight cylindrical work, because it is liable to make the surface of the work more or less wavy. It is, however, almost always used for cutting off and for cutting down shoulders, for which purpose it is highly advantageous. For circumferential work on cylindrical surfaces, an ordinary chisel is mostly employed, the position in which it is held to the work causing it to scrape rather than cut. A worn-out paring chisel is as good as any, but in any event it should be a short one. Such a chisel is shown in Fig. 2681, the position in which it is held being illustrated by *A*, which represents a section of a piece of cylindrical work; *B* representing the chisel, and *C* the hand-rest. Some pattern-makers prefer to increase the keenness of this tool by holding it so that the plane of its length lies in the direction denoted by the dotted line *D*; this, however, renders it more likely to rip into the work, and the position shown is all that is necessary, provided the cutting edge be kept properly sharpened. This chisel is also used on side faces.

Still another tool, sometimes used for finishing plain cylindrical surfaces and side faces, is that shown in Fig. 2682 at *A*. It is used in the same manner and relative position as the chisel shown in Fig. 2681.

Tools for Finishing Hollows.—For finishing hollows, which should first be roughed out with the gouge, the form of tool shown at *B* in Fig. 2682 should be used. Several of these tools, of various sizes, should be kept; they are used in the same position as the finishing chisel shown in Fig. 2681. The tool shown at *C* in Fig. 2682 is used upon large work, and is advantageous because it presents

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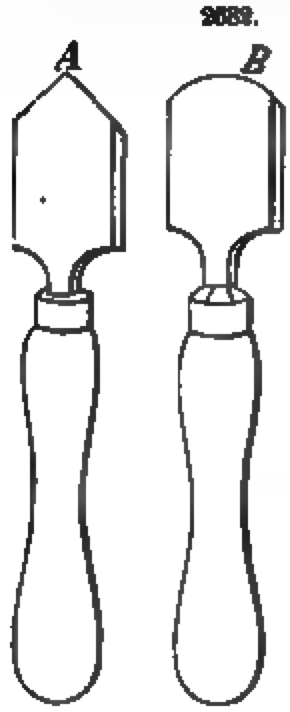

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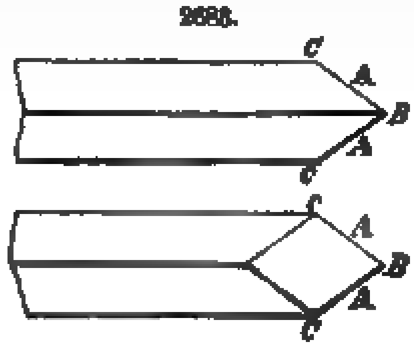

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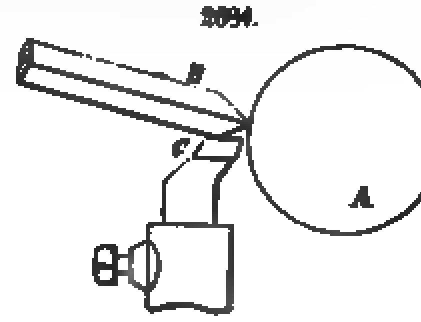

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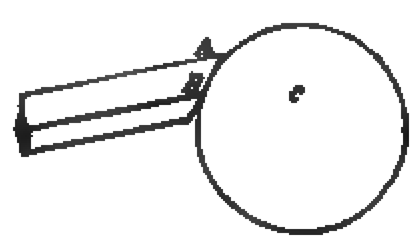


less surface of cutting edge in proportion to the depth of the cut than does the gouge; and, in consequence, it is less liable to cause the work to jar or tremble. It is usually made about 2 ft. long, which enables the operator to hold it very firmly and steadily. It is used with its top face lying horizontally, and should be kept keen. *D* is a round-nosed tool for finishing hollows.

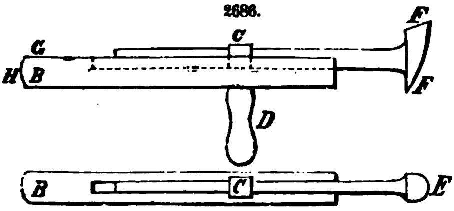
II. For Metals.—The process of hand-turning in metal has been to a great extent superseded by the work of special machine-tools, designed to perform their duties partly or wholly by automatic movements. In these machines steel tools only are used, or steel tools in conjunction with emery-wheels. For small quantities of promiscuous work, however, hand-turning tools are essential, because in skillful hands they will perform more duty in a given time than tools used (upon small and irregular work) in the slide-rest.

The Graver.—Of all hand metal-cutting tools, the graver is the most important. It is formed by grinding the end of a piece of square steel at an angle, as shown in Fig. 2683, the edges *A* and point *B* being the cutting parts, while *C* serves as the fulcrum or heel of the tool. The graver can be applied either to rough out or finish steel, wrought iron, cast iron, brass, copper, or other metal, and will turn work to almost any desired shape. Held with the heel pressed firmly against the hand-rest (the point being used to cut, as shown in Fig. 2684, *A* being the work, *B* the graver, and *C* the lathe-rest), it turns very true and cuts easily and freely. This, therefore, is the position in which it is held to rough out the work. The heel of the graver, which rests upon the hand-rest, should be pressed firmly to the rest, so as to serve as a fulcrum and at the same time as a pivotal point upon which it may turn to follow up the cut as it proceeds. The cutting point of the graver is held at first as much as convenient toward the dead centre, the handle in which the graver is fixed being held lightly by both hands, and slightly revolved from the right toward the left, at the same time

that the handle is moved bodily from the left toward the right. By this combination of the two movements, if properly performed, the point of the graver will move in a line parallel to the centres of the lathe, because, while the twisting of the graver-handle causes the graver-point to move away from the centre of the diameter of the work, the moving of the handle bodily from left to right causes the point of the graver to approach the centre of that diameter; hence the one movement counteracts the other, producing a parallel movement, and at the same time enables the graver-point to follow up the cut, using the heel as a pivotal fulcrum, and hence obviating the necessity of an inconveniently frequent moving of the heel of the tool along the rest. The most desirable range of these two movements will be very readily observed by the operator, because an excess in either of them destroys the efficacy of the heel of the graver as a fulcrum, and gives it less power to cut, and the operator has less control of the tool. The handle in which the graver is held should be sufficiently long to enable the operator to grasp it with both hands and thus to hold it steadily, even though the work may run very much out of true. To cut smoothly, as is required in finishing work, the graver is held as shown in Fig. 2685, *C* being the work. The edge on the end of the graver, and between the corners *A* and *B* of the graver, performs the cutting operation. By holding the graver in the positions described, and in various modifications of the same, the work may obviously be turned parallel, with either round edges, curves, or square shoulders; and it is possible to turn almost any shape with this one tool. For finishing curves, however, the end of the graver (the cutting edge on the end and between the curves) should be rounded. Even parallel work should be finished by being filed with a smooth file while the lathe is running at a high speed. As little as possible should, however, be left for the file to do, because it cuts the softer veins of the metal more readily than the rest, and therefore makes the work out of true.

The Heel-Tool.—In those exceptional cases in which, for want of a lathe having a slide-rest, it becomes necessary to perform comparatively heavy work in a hand-lathe, the heel-tool should be employed. This tool is an excellent one for roughing work out, and will take a very heavy cut for a hand-tool. A heel-tool is shown in Fig. 2686, which is a piece of square bar steel forged at the end to form the cutting edge. The body of the square part is held (in a groove formed in the wooden handle *B*) by an iron strap *C*, which is tightened by screwing up the under handle *D*, which contains a nut into which the spindle of the strap *C* is screwed as the handle *D* is revolved. The heel *F* of the tool is tapered, so that it will firmly grip the face of the lathe-rest, the cutting edge *E* being rounded as shown above. The tool is held by grasping the handle *B* at about the point *G* with the left hand, and by holding the under handle *D* in the right hand, the extreme end *H* of the handle being placed firmly against the right shoulder of the operator. The heel *F* of the tool must be placed directly under the part of the work it is intended to turn, the cutting edge *E* of the tool being kept up to the cut by using the handle *D* as a lever, and the heel *F* of the tool as a fulcrum. Not much lateral movement must, however, be allowed to the cutting edge of the tool to make it follow the cut, as it will get completely beyond the manipulator's control and rip into the work. Until some knowledge of the use of this tool has been acquired, it is better not to forge the top of the cutting edge *E* too high from the body of the tool; since the lower it is, the easier the tool is to handle. The heel-tool should, like the graver, be hardened right out; but in dipping it, allow the heel *F* to be a little the softer by plunging the end *E* into the water about half way to *F*, and then, after holding it in that position for about four seconds, immerse the heel *F* also. After again holding the tool still for about six seconds, withdraw it from the water and hold it until the water has dried off the point *E*; dip the tool again, and quickly withdraw it, repeating this latter part of the operation until the tool is quite cold. The object of the transient dippings is to prevent the junction of the hard and soft metal from being a narrow strip of metal, in which case the tool is very liable to break at that junction. The tool should be so placed in the handle that there is only sufficient room between the cutting edge and the end of the handle to well clear the lathe-rest, and should be so held that the handle stands with the end *H* raised slightly above a horizontal position, the necessary rake being given by the angle of the top face at *E*. It is only applicable to wrought iron and steel; but for use on those metals, especially the latter, it is a superior and valuable hand-tool.

2686.



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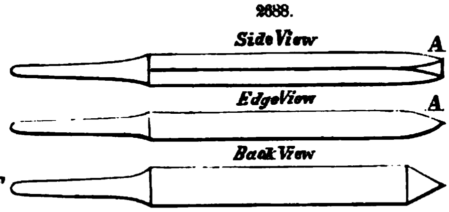

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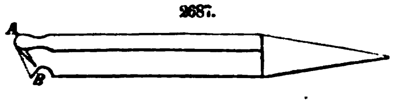

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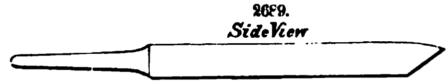

Curve-Turning Tool.—For turning out curves the tools are formed as shown in Fig. 2687, the shape of the cutting edge *A* being modified to suit the work; the amount of cutting edge should not, however, exceed three-eighths of an inch, or the tool will jar or chatter, as it is termed, and will produce wave-like marks upon the work. The heel of the tool at *B* is made as shown, so as to grip the lathe-rest firmly, the point being used as a fulcrum wherefrom to move the tool to its lateral cut.

Side-Tool.—For facing up the ends of iron or steel work, or the side faces of heads or collars, the side-tools shown in Figs. 2688 and 2689 are employed. A worn-out saw-file is an excellent thing to make a side-tool of, because the teeth grip the rest and prevent the tool from slipping. It is not necessary to soften the file at all, but (for either kind) merely to grind it as shown, *A* being in each case the cutting edge. The tool shown in Fig. 2688 has two cutting edges, one of which rests upon the hand-rest while the other is cutting, which does not in any way damage the edge, but causes the tool to hold very firmly to the rest, and hence to turn very true. It possesses the further advantages that it cuts very freely, and that its point can, by reason of its thinness, approach much nearer to the centre of the work without coming into contact with the lathe-centre. Except for heavy work, it is by far the best tool in every respect, nor would the other have been presented at all, save that it is very largely employed when it is required to perform heavy duty. Both of these tools are slightly rounded in the length of their cutting edges, and are kept sharpened from the end about half an inch back. If their cutting edges are smoothed by the application of an oilstone, they will give a very clean and smooth polish to the work. The rest should be set at such a height that the cutting edge of the tool is slightly above the horizontal centre of the work; and the tool should be so held that its side face stands nearly parallel with the end face of the work, the cutting edge being held slightly inclined toward the work, which will give to the tool-edge the necessary clearance. Any excess of this inclination renders the tool liable to turn out of true, and destroys its cutting edge very rapidly.

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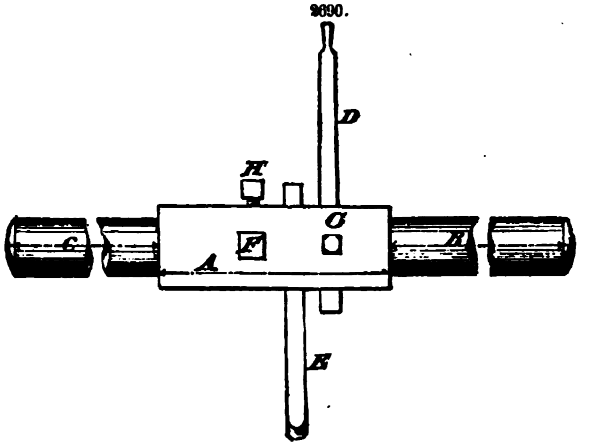

The Clockmaker's Hand-Turning Tool.—By means of this tool pieces of work may be produced in duplicate, exact in diameter, length, and form, and this can be readily done without the use of calipers or gauges. By a very simple arrangement the tool can be used on almost any hand-lathe, and made to operate as a special tool upon a very wide range of small work.

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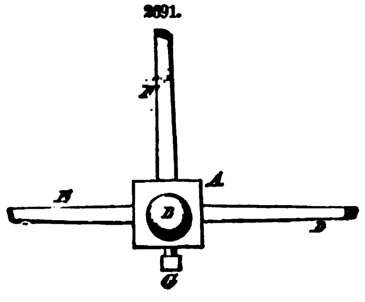

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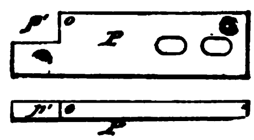

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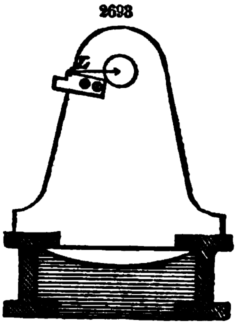

The device consists of a stock or holder as shown in Fig. 2690, the middle of which, denoted by *A*, is square, and contains three or four square slots with a set-screw to each slot to hold different turning tools. Each end of the stock is turned parallel, as denoted by *B C*. In Figs. 2690 and 2691, *D*, *E*, and *F* are the tools, and *G H* are the set-screws. Fig. 2692 presents top and side views of a plate, of which there must be two, one to fasten on the head-stock and one on the tail-stock of the lathe, as shown in Fig. 2693.

In Fig. 2694 the manner of using the tool is shown, similar letters of reference denoting similar parts in all the figures. The plates *P P* are bolted by the screws *I I*, *J J*, to the head-block *H* and the tail-stock *T* of the lathe. The tool-holder is placed so that the cylindrical ends *B C* rest on the ends of these plates and in the angles *p′ p′*. The cutting tool *D* is sustained as shown upon the lathe-rest *R*. In use, the operator holds the stock *A* in his hands in the most convenient manner, using the tool *E* as a handle when there is a tool in the position of *E*. The cutting point of the tool is pressed up to the work *W*, and the feed is carried along by hand. It is obvious, however, that when the cylindrical ends *B C* of the holder come against the shoulders *o o* of the plates *P P*, the tool cannot approach any nearer to the diametral centre of the work; hence the diameter to which the tool will turn is determined by the distance of the shoulders *o* of the plates *P* from the centre of the lathe-centres. In carrying the cut along, it is also obvious that the lateral travel of the stock or holder must end when the end of the square part *A* comes against the side face of either of the plates. In the engraving the tool *D* is shown cutting a groove in the work *W*, while the shoulder of the holder is against the plate fastened to the lathe tail-stock *T*; and so long as the

operator, in each case, keeps the shoulder against that plate, the grooves upon each piece of work will be cut in the same position, for it will be observed that the position in the length of the work performed by each tool is determined by the distance of the cutting part of each tool from the end of the square part A of the tool-holder. All that is necessary then is to adjust each tool so

2694.

that it projects the proper distance to turn the requisite diameter, and stands the required distance from the shoulders of the square to cut to the desired length, and when once set error cannot occur.

This plain description of the device, however, does not convey an adequate idea of its importance. Suppose, for example, that it is required to turn a number of duplicate pieces, each with a certain taper. All that is necessary is to adjust the plates P in their distances from the lathe-centres. If the large end of the taper, on the work, is required to stand nearest the lathe head-stock H, the plate P on the head-stock must be moved until its shoulder o is farther from the lathe-centre. If, however, the work requires to be made parallel, the plates P must be set the same distance for the axial line of the centres. If it be desired to have a parallel and a taper in proximity upon the same piece of work, the tool must have one of its cylindrical ends taper and be used upon the taper part of the work. All kinds of irregular work may be performed by varying the form of the cylindrical ends of the tool-holder. In this event the shoulders o of the plates P should be made V-shaped and of steel, and hardened.

Tools specially adapted for Brass-Turning.—The hand-tools for brass work are generally distinguishable from the fact that the top or uppermost face of the tool is made straight, that is, has no top rake. For roughing out brass work, the best and most universally applicable tool is that shown in Fig. 2695, which is to brass work what the graver is to wrought iron or steel. The cutting point A is round-nosed. The hand-rest should be set a little above the horizontal centre of the work, and need not be close up to the work, because comparatively little power is required to cut brass and other soft metals, and therefore complete control can be had over the tool, even though its point of con-

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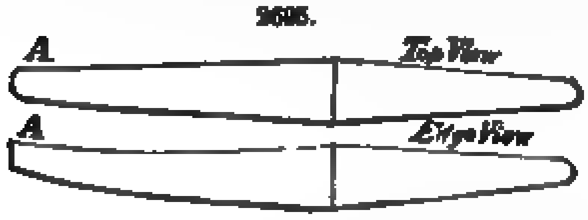

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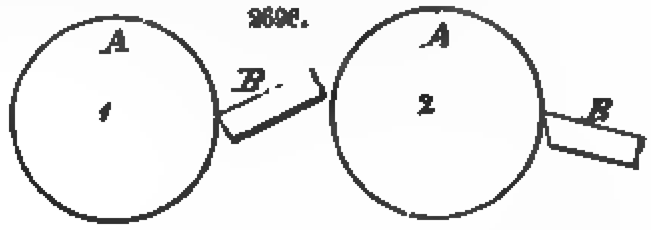

tact with the rest be some little distance from its cutting point. The best method of holding and guiding is to place the forefinger of the left hand under the jaw of the hand-rest, and to press the tool firmly to the face of the rest by the thumb, regulating the height so that the cutting is performed at or a little below the horizontal centre of the work.

Scrapers for Brass Work.—To finish brass work, various-shaped tools termed scrapers are employed. The term scraper, however, applies as much to the manner in which the tool is applied to the work as to its shape, since the same tool may, without alteration, be employed either as a scraping or a cutting tool, according to the angle of the top face (that is, the face which meets the shavings or cuttings) to a line drawn from the point of contact of the tool with the work to the centre line of the work, and altogether irrespective of the angles of the two faces of the tool whose junction forms the cutting edge. To give, then, the degree of angle necessary to a cutting tool, irrespective

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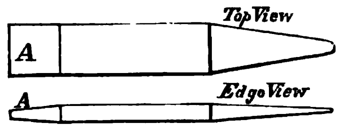

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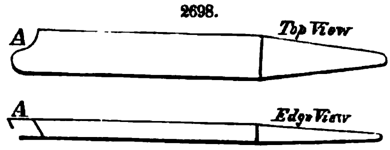

of the position in which it is held, is altogether valueless, as will be perceived by considering Fig. 2696, *A* being in each case a piece of work, and *B* a tool. The tool-edge as applied in No. 1 will act as a scraper, whereas in No. 2 it will act as a cutting tool. Fig. 2697 represents a flat scraper for finishing brass, *A* being in each case the cutting edge, since the tool may be turned upside down. The end of this tool may be and frequently is ground at an angle, especially in those cases where, for some required purpose, the tool is made of a particular shape, such for instance as in the case of the tool shown in Fig. 2698, the angle being shown at *A*. On all brass work, it is, however, better to dispense with an angle. Fig. 2699 represents a scraper (*A* being the cutting edge) designed for operating close down to the lathe-centre or in a square corner, such as is formed at the junction of a head or collar upon a shaft or bolt. This tool may also be turned upside down, so as to form a right-hand or left-hand tool. Scrapers will cut more freely if applied to the work with the edges as left by the grindstone; but if they are smoothed after grinding by the application of an oilstone, they will give to the work a much smoother and higher degree of finish. They should be hardened right out for use on cast iron, and tempered to a straw color for brass work. If the scraper jars or chatters, as it will sometimes, by reason of its having an excess of angle, as shown in Fig. 2698, or from the cutting end being ground too thin, a piece of leather placed between the tool and the face of the rest will obviate the difficulty.

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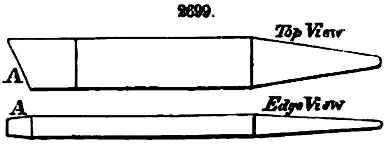

J. R.

LATHE-TOOLS, SCREW-CUTTING. Hand-Tools.—For cutting screws or threads in the lathe by hand, the tools shown in Figs. 2700 and 2701 are employed, the former being used upon external or male threads, and the latter upon internal or female threads. A fine groove of the necessary pitch of thread is first traced upon the work by a graver, and the chaser is then applied to the groove as a comb, being forced against the work by hand pressure.

To make a chaser, a tool termed a hob is made to revolve between the centres of the lathe. The workman takes a blank screw tool, which must be well annealed, and applies its face to the revolving hob, being careful to hold the tool very firmly, yet not to allow the hob at the commencement to bite too greedily, and supplying oil to the surface of the hob or tap, which essentially assists the operation. The blank tool may be held either above or below the centre of the hob. The latter is shown in Fig. 2702, and is in some respects preferable to the former, as it affords a better purchase

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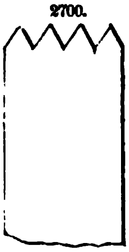

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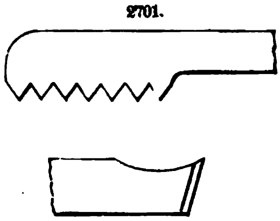

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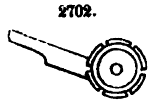

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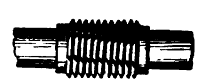

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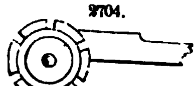

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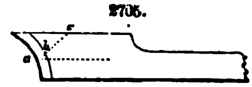

for the tool. The method of cutting screw-tools practised in Manchester is in many respects similar to that we have just described, except that it requires the aid of change-wheels and a slide-lathe. Nevertheless, as many of the details are common to both, the observations we are about to make will, in some measure, apply to manual as well as mechanical power.

The first thing is to cut the hob, or hub, which is effected by a self-acting slide-rest. It is simply a screw cut on a solid cylinder of cast steel, with diagonal grooves cut across the thread of the screw to act as cutters, as shown in Fig. 2703; the two necks of the hob have concave holes drilled in the ends to carry the centres of the lathe. The hob is placed between the centre points of the lathe, by means of a dog or catch attached to one end in the usual way. Change-wheels are then put on to connect the mandrel or spindle with the guide-screw of the lathe, which carries along the slide-rest. The wheels are so arranged that one turn of the mandrel causes the slide-rest to travel a distance exactly equal to one thread. The blank which is to be cut is firmly screwed down in the tool-box

of the slide-rest, and made to stand above the centre of the hob, as shown in Fig. 2704. It is then pressed by the screw of the slide-rest against the hob, and the lathe being put in motion causes the tool to traverse along and against the hob, cutting it as deep as may be thought necessary. The face of the tool, when cut, is a segment of a circle, varying, of course, according to the diameter of the hob.

Fig. 2705 is a side view of the tool in this condition; but this form is not found sufficiently economical in practice, since it can only be ground and sharpened to a particular point, as to *b*; for when ground to *b*, as from *a* to *c*, it ceases to cut, owing to the top of the tool being then as far from the screw to be cut as the bottom. The method adopted to obviate this difficulty is to give the tool an angular instead of a circular face, and this is managed in the following way: The screw-tool is removed from the slide-rest, and, as the hob revolves, the workman elevates and depresses the end of the tool which is in his hand, so as to present different points of the face to the cutting action of the hob, until by degrees he succeeds in obtaining a perfectly angular face, which allows the tool to be ground nearly or quite to the bottom, with a certainty of preserving a good cutting edge. To finish the round top and bottom thread in the lathe, a chaser is necessary, it being impracticable to use a single V-tool with a projecting lip to round off the tops of the thread, because such a tool would require to be sharpened by grinding away the top face, and in that case the clearance of the tool would cause its angles, and hence the angle of the thread it will cut, to alter at each grinding. It is the usual practice to use a chaser, that is, a screw-cutting tool having several teeth. The disadvantage of this system is that the chaser must be cut from a hob, and if the hob is cut of the correct pitch it is liable to become of incorrect pitch in the hardening process, because the steel usually increases in diameter and shrinks in length from being hardened; hence the pitch of the hob will be to that extent finer when hardened. The chaser cut from the hob again shrinks from the hardening, and thus

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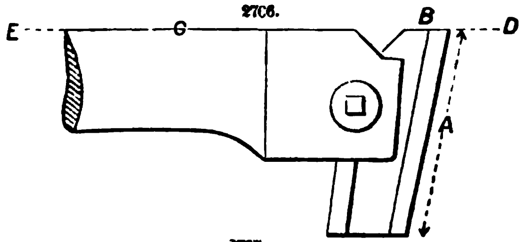

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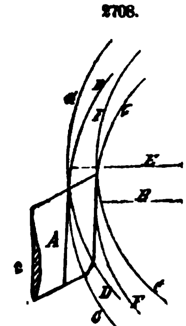

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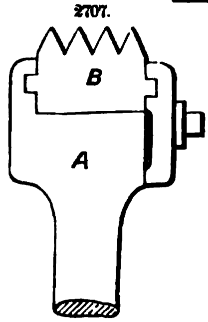

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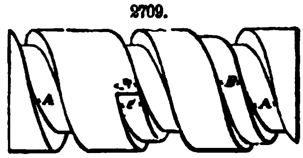

the error is doubled. To remedy this defect, Messrs Pratt & Whitney have devised a new kind of chasing tool, to be held in a tool-holder as shown in Figs. 2706 and 2707. The teeth in the direction of their length *A* are made straight instead of in a hollow curve, as when cut by a hob, and the angles of the teeth are corrected after hardening. This, however, is an expensive tool to make, and is somewhat unhandy; so that when it is considered how much more easy and ready of accomplishment it is to grind a plain turning tool to the requisite angle for either an external or an internal thread, it becomes apparent that the United States standard thread possesses important practical advantages. Furthermore, a thread can be cut much more true upon wrought iron or steel with a tool having a single cutting tooth than with one possessing several such teeth, because the latter are more apt to follow the inequalities in the texture of the metal.

An important consideration in screw-cutting is the position of the tool relative to the work, since by a variation in the height of the tool the depth of the thread and therefore its angles may be altered. Suppose, for example, that *A*, Fig. 2708, is the chaser or screw-cutting tool, and *B* a horizontal line passing through the centre of the work; then the depth of the thread cut will be that of the distance between the lines *C* and *D*. If, however, the horizontal line *E* passes through the centre of the work, the depth of thread cut will be the distance from *F* to *G*; which being greater than that of *C D*, it follows that the height of the tool influences the depth of the thread cut. In the case of using a chaser, the teeth must be held to the work in the same relative position as they were to the hob which cut them, no matter whether the top face of the teeth is ground horizontally level, is given rake or keenness to make them cut clean, or is ground at an obtuse angle, as is necessary upon brass work. It is, therefore, essential to insure that the position of the chaser be correct, and to try the depth of the thread during the latter part of the process of

thread-cutting. When, however, a turning tool ground to the correct angle is used, the top face being left level and placed horizontally level with the centre of the work, the thread cut will inevitably be of the correct angle and depth. In grinding such a tool to resharpen it, the top face need not be touched, and hence the height of the tool once set will always remain correct; whereas, in the case of a chaser, at each grinding the height of the tool is altered, necessitating its readjustment, and a trial with a thread-gauge to test the accuracy. If the tool requires an incline upon the top face to make it cut clean and well, the V turning tool has still the advantage, inasmuch as when once the top face is set it need not be altered, the grinding being done on the V-faces, or side angles, whereas the chaser can only be sharpened upon the the top face.

Power Tools.—Lathe-tools for cutting screws have necessarily, from the nature of their duty, a comparatively broad cutting surface, rendering them very subject to spring. Those used for V-threads, being ground to fit the V of the thread, are, in consequence, weak and liable to break; to avoid which they should only be given enough bottom rake to well clear the thread, and top rake sufficient to make them cut clean. They are used at a slow rate of cutting speed, and may therefore be lowered to a straw-colored temper (as reducing the temper strengthens a tool). Firmness and strength are of great importance to this class of tool, so that it should be fastened with the cutting edge as near to the tool-post as is convenient. For use on wrought iron, it is sometimes given side rake; but this is not of necessity, and is of doubtful utility, because the advantage gained by its tendency to assist in feeding itself is quite counterbalanced by its increased liability to break at the point. It should always be placed to cut at the centre of the work. For use on brass, it must be ground on the top face to an inclined plane, of which the cutting point is the depressed end; that is to say, it must have negative top rake.

For cutting square threads, a tool with the sides ground away beneath sufficiently to well clear the sides of the thread is used. If the pitch of the screw to be cut is very coarse, a tool nearly one-half of the width of the space between one thread and the next should be employed, so as to avoid the spring which a tool of the full width would undergo. After taking several cuts, the tool must be moved laterally to the amount of its width, and cuts taken off as before until the tool has cut somewhat deeper than it did before being moved, when it must be placed back again into its first position, and the process repeated until the required depth of thread is attained. Fig. 2709 represents a thread or screw during the above-described process of cutting. *A A* is the groove or space taken out by the cuts before the tool was moved; *B* represents the first cut taken after it is moved; *C* is the point to which the cut *B* is supposed (for the purpose of this illustration) to have traveled. The tool used having been a little less than one-half the proper width of the space of the thread, it becomes evident that the thread will be left with rather more than its proper thickness, which is done to allow finishing cuts to be taken upon its sides, for which purpose the side-tool is brought into requisition, care being taken that it is placed true, so as to cut both sides of the thread of an equal angle to the centre line of the screw. In cutting V-threads of a coarse pitch, the tool may be made less in width than the required space between the threads demands, so that it may be moved a little laterally in order to take a cut off one side of the thread only at a time, by which means a heavier cut may be taken with less liability for the tool to spring in; but the finishing cut is better if taken by a tool of the full width or shape of the thread.

Fig. 2710 represents a tool for cutting an outside V-thread in brass work. When, however, the tool-point must of necessity stand far out from the tool-post, it must be given negative top rake, to

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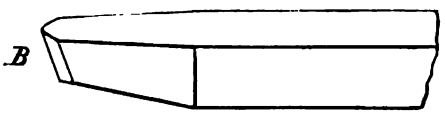
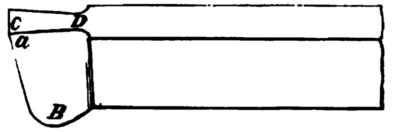


2711.



make it cut smoothly and prevent its jarring. . To adapt this tool to cutting V-threads on iron, it is only necessary to give it top rake.

For cutting square threads on brass work, the tool shown in Fig. 2711 should be used. The thickness at *C* must however be made sufficiently greater than that at *B* to clear well the sides of the thread. This will answer very well for threads of fine pitches, but for coarse ones the part from *C* to *D*, while still slightly thicker at *C* to give the tool clearance, should also be atwist with the body of the tool-steel, the amount of the twist agreeing with the angle of the thread to be cut, so as to leave the tool as strong as possible. (See also Screw-cutting Machines, Screw-Thread, and Taps and Dies.) J. R.

LATHE-TOOLS, TURNING (SLIDE-REST). While the operation of turning in the lathe is accomplished with more facility, truth, and expedition than any other metal-cutting process performed by steel tools in conjunction with a machine, yet at the same time it requires more manipulative skill than any other, for the following reasons: 1. The range of work operated upon in the lathe is vastly more extensive. 2. The work requires to be finished in the lathe, and is not supposed to be operated upon after leaving the lathe by files or other truing or adjusting tools. 3. The speed at which the work travels covers a greater range, and is left more largely dependent upon the judgment of the operator. 4. The cutting operation is in a majority of instances continuous. 5. The variations in form as well as in the angle of the facets of the tool are more multitudinous. 6. The conditions under which the tools operate may be, and are in actual practice, widely divergent.

The considerations which determine the proper form of a turning tool are the nature of the material to be cut, the distance of the tool-edge from the tool-post or rest, and in conjunction with these

the angles of the facets whose line of junction forms the cutting edge, combined with the position of the top face or facet with relation to the work. As a general principle, the more acute these angles are one to another, the keener and the weaker is the cutting edge of the tool. In Fig. 2712, *A* denotes the top and *B* the bottom face of the tool. Top rake is the name given to the inclination of the face *A* in the direction of the arrow, and negative top rake is the name given to the angle of the face *A* when its point is the lowest, as would be the case if the plane of that face was as denoted by the line *E*. The angle of the bottom face to the line *C D* is termed the bottom rake or clearance. Thus the line *F* denotes by its variation from a right angle the bottom rake. The cutting value of a tool is principally determined by the top rake with relation to the work, and this fact it is which determines whether a tool having any definite angles of facet to form its cutting edge shall act as a cutting or as a scraping tool. Suppose, for instance, that we have four turning tools of exactly similar form, and apply them to the piece of turning work shown in section in Fig. 2713 at *A*. The action of the tool held in position 1 will be to scrape; in position 2, to cut and scrape at once; in position 3, to cut moderately well; and in position 4, to cut freely. On referring to the dotted lines it will be observed that the angle or top rake of the tool to the work is but slightly varied. Tools for wrought iron require the angle or rake of the top facet to be, as a rule, as shown in position 4; but if the cutting edge of the tool stands far out from the tool-post or clamp, this rake must be made to assimilate toward position 3. Tools for cast iron require the top rake to be similar to that shown in position 3; but if the tool stands far out, or is slight in proportion to its duty, the rake must be modified toward that shown in position 2. Tools for brass require the top face to be in position 2, while if the tool-edge protrudes far from the tool-post, negative top rake, as shown in position 1, must be employed. The distance of the cutting edge from the tool-post or tool-holder of the lathe, then, is an important element in determining the necessary amount of top rake; and instead of defining

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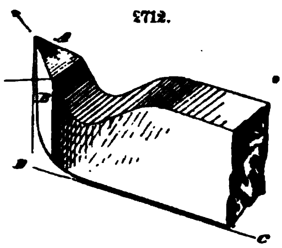

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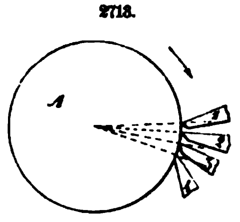

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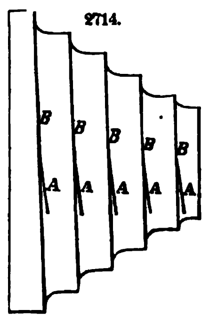

that rake as ranging between a certain number of degrees of angle, it is preferable to explain the principle from which its amount is under ordinarily varying conditions determined in actual practice. It is in fact altogether erroneous to give a fixed degree of angle as proper for a lathe-cutting tool, because the size of the work and the rate of feed, independent of the tool itself, regulate to a large degree the angle at which the tool stands in relation to the work.

Suppose we give to a common front tool an angle of the bottom face of say 6°; let us see how such a definite angle will operate in practice. In Fig. 2714, *A* represents in each case the 6° of angle on the side face of the tool, while *B* represents the angle of the respective cuts. The rate of feed is alike for the respective diameters, and we find that with a constant degree of angle and a constant rate of feed, the angle of the tool to the cut varies with every varying diameter; and furthermore, the clearance of the tool becomes greater as the size of the work operated upon is increased, whereas in good practice the exact opposite is required. To maintain a fixed degree of angle upon the side face of the tool with relation to the cut, the tool-angle must be varied according to the size of the work and the rate of feed. The size of the work, the hardness of the metal, the size of the tool-steel, the depth of the cut to be taken, the distance of the cutting edge from the tool-clamp, and lastly the shape and strength of the cutting end of the tool itself, are all considerations which go to determine the proper angle for the top face.

It is always desirable, circumstances permitting, to place nearly all the rake upon the top face of the tool. In those cases (to be hereafter specified) in which the top rake must, from the nature of the work, be modified, the tool must be given the necessary keenness by an addition of bottom rake. These top and bottom faces, taken one in conjunction with the other, form a wedge, and all cutting tools are nothing more than wedges. The strain sustained by the top face is not alone that due to the severing of the metal, but that in addition which is exerted to break or curl the shaving, which would, if not obstructed by the top face, come off in a straight line, like a piece of cord being unwound from a cylinder; but on coming into contact with that face immediately after it has left the cutting edge, the shaving is forced out of the straight line, and takes a circular form of more or less diameter according to the amount of top rake possessed by the tool. The direction of the whole strain upon the top face is at a right angle to it, as denoted in Fig. 2715 by the line *D*, *A* representing the work, *B* the tool, and *C* the shaving. It will be readily perceived then that if a tool possessing so much top rake is held far out from the tool-post or clamp, or is slight in body, any springing or deflection of the tool will cause the tool-point to take a deeper cut, and that the tendency of the strain upon the top face is to draw the tool deeper into its cut. A plain cut (either inside or outside) admits of the application of a maximum of front or top rake, and of a minimum of bottom or side rake; but a tool of this description, if used upon work having a break in the cut (such as a keyway or slot),

would run in and break off from the following causes: If the strain upon the tool were equal in force at all times during the cut, the spring would also be equal, and the cut therefore a smooth one; but in taking a first cut, there may be, and usually is, more metal to be cut off the work in one place than in another; besides which there are inequalities in the texture of the metal, so that, when the harder parts come into contact with the tool, it springs more and cuts deeper than it does when cutting the softer parts, and therefore leaves the face of the work uneven. If less rake be given to the tool on its top and more on its side or bottom face, as is represented in Fig. 2716, *A* being the

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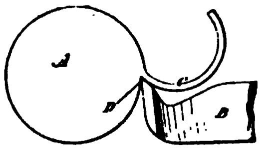

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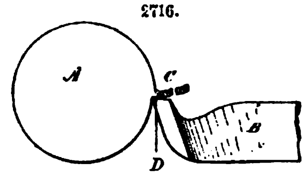
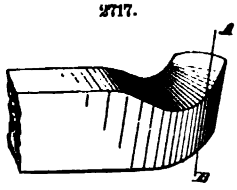


shaft as before, *B* the tool, and *C* the shaving, the line *D* is the direction of the strain put upon the tool by the shaving, which has but very little if any tendency to spring the tool into its cut. It follows then that, if two tools are placed in position to take an equal cut off similar work, that which possesses the most top rake, while receiving the least strain from the shaving, receives it in a direction the most likely to spring it into its cut. It must not, therefore, be used upon any work having a tendency to draw the tool in, nor upon work to perform which the tool must stand far out from the tool-post, for in either case it will spring into its cut.

When, in consequence of the top face having but very little rake, it becomes necessary to give the cutting edge keenness by the application of a maximum of bottom rake, the tool becomes proportionately weak, as is shown in Fig. 2716, in which it will be noted that the cutting edge is comparatively weak, and is hence liable to break. Taking all these considerations into account, we arrive at the tool shown in Fig. 2717 as representing the most desirable proportions of top and bottom rake for ordinary purposes upon light work. Such a tool, however, is not adapted to taking very heavy cuts, for which duty the tool is given what is termed side rake; that is to say, the top face of the tool possesses angle across its width, as denoted in Fig. 2718 at *A*. The amount of power required to feed a lathe-tool or other metal-cutting tool into its cut at the same time that the tool is cutting, is considerable when a heavy cut is being taken; and the object of side rake is not only to make the tool more keen without sacrificing its strength, but to relieve the feed-screw or gearing of a part of this strain by giving the tool a tendency to feed along and into its cut, which is accomplished by side rake as follows. Suppose, in Fig. 2718, *A* to be a cross-section at *A B* of the tool shown in Fig. 2717, *W* representing the work and *S* the shaving; then the pressure due to bending the shaving gives the tool a tendency to feed itself along and into the cut. The direction of the pressure due to bending the shaving has in fact followed the direction of the top rake, decreasing its tendency to run or spring in, with a corresponding gain in the above-mentioned inclination to feed itself along or into its lateral cut.

When side rake is called into use, a corresponding amount of front rake must be dispensed with, or its tendency to feed itself becomes so great that it will swing round, using the tool-post as a centre (feeding rapidly into the cut), spring in, and break from the undue pressure, particularly if the lathe or machine has any play in the slides. So much side rake may be given to a tool that it will feed itself without the aid of any feed-motion, for the force required to bend the shaving (in heavy cuts only) will react upon the tool, forcing it up and into its cut, while the amount of bottom rake, or clearance, as it is sometimes called, may be made just sufficient to permit the tool to enter its cut to the required thickness of shaving or feed and no more; and it will, after the cut is once begun, feed itself, and stop of itself when the cut is over. But to grind a tool to this exactitude is too deli-

2717.



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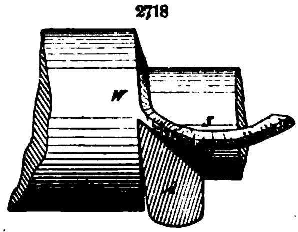

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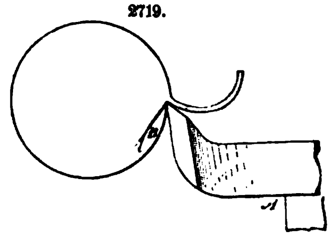

cate an operation for ordinary practice. The experiment has, however, been successfully tried; but it was found necessary to have the slides of the lathe very nicely adjusted, and to take up the lost motion in the cross-feed screw.

For roughing out and for long continuous cuts, this tool is the best of any that can be used, because it presents a keen cutting edge to the metal, and the cutting edge receives the maximum of support from the steel beneath or behind it. It receives less strain from the shaving than any other, and will, in consequence of these virtues combined, take a heavier cut, and stand it longer, than any other tool; but it is not so good for taking a finishing cut as one having front rake, as shown in Fig. 2716.

Having determined the position of the requisite rake, the next consideration is that of the proper height of the cutting edge from the body of the tool. This height varies in practice because of the differences in height between the top face of the slide-rest and the horizontal centre of the lathe-centre, which distance varies according to the size of the steel necessary for different sizes of lathes, and according to the ideas of the maker of the lathe.

In Fig. 2719 is shown a tool having a maximum of such height, the object being to forge the cutting end of the tool long at the angle, so that it will afford more material, and can therefore be ground up on the grindstone a greater number of times without being reforged. The objections to such a tool, however, are very grave, for the following reasons. The pressure of the cut must inevitably cause the tool to spring or bend downward, and the fulcrum off which this spring takes place is at the edge of the slide-rest shown at *A* in Fig. 2719. If then we draw from the point *A* the section of a circle *B*, the direction of the latter as denoted by the arrow will be the direction in which the spring of the tool will take place. In addition to this defect, the tool is difficult to forge, and during that process the grain of the steel is considerably upset, which deteriorates it. In the next place, it is exceedingly difficult to grind because of the tediousness of the operation, which arises from the length of the face presenting so much surface requiring to be ground away. The tools shown in Figs. 2716 and 2717 are of proper height; their conformation renders them easy to forge and to grind, while the full strength is retained.

The next consideration is that of the requisite form for the *nose* of the tool, as the extreme point or end of the cutting edge is termed. Round-nosed tools, such as shown in Fig. 2720, have more cutting edge to them (the depths of the cuts being equal) than the straight-nosed ones shown in Figs. 2717 and 2718, receiving as the result more strain from, and becoming more liable to run into or out from, the cut. If sufficient rake is given to the tool to obviate this defect, it will, under a heavy cut, spring in. It is, however, well adapted to cutting out curves, or taking finishing cuts on wrought-iron work which is so strong and stiff as not to spring away from it, because it can be used with a coarse feed without leaving deep or rough tool- or feed-marks; it should, however, always be used with a slow speed. On coming into contact with the scale or skin of the metal, in case the work will not true up, it is liable to spring away from its cut. If held far out from the tool-post, it is apt to jar or chatter; and unless the work and the tool are both firmly held, it is liable to cut deeper into the softer than into the harder parts of the metal. The angles or sides of a cutting tool must not of necessity be quite flat (unless for use on slight work, as rods or spindles), but slightly curved, and in all cases rounded at the point, at least as much as in the tool shown in Fig. 2721. If the angles

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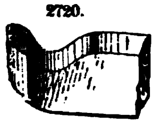

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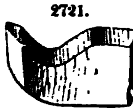

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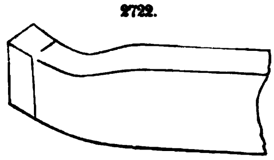

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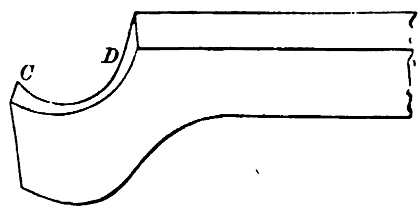


were left flat and the point sharp, the tool would leave deep and ragged feed-marks; the extreme point, wearing away quickly, would soon render the tool too dull for use, and the point would be apt to break.

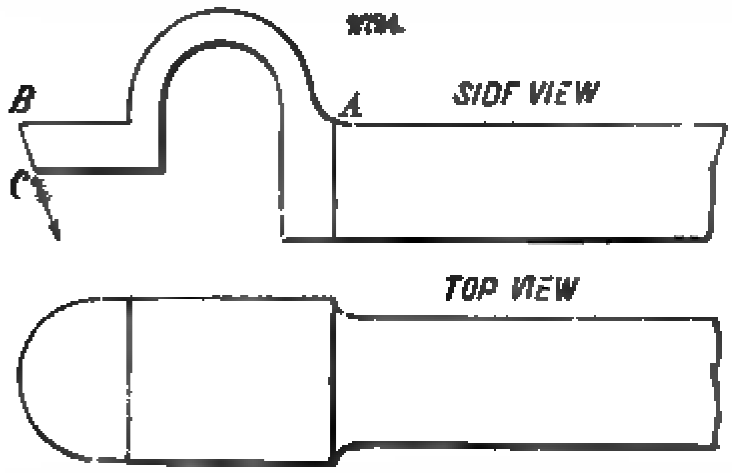
For the finishing cuts of heavy cast-iron work, which is not liable to spring, the broad square-nosed tool shown in Fig. 2722 is the best. On ordinary cast-iron work a feed can be used with this tool almost as broad at a cut as the nose of the tool itself; providing, however, that it is set in position with great exactitude, so that its flat nose or front will be even or true with the face of the work it is intended to cut, and that it is held as close in to the tool-post as it can conveniently be; and that, if fed by hand, it be fed evenly, because all tools possessing a broad cutting surface are subservient to spring, which spring is always in a direction (as in this case) to deepen the cut; so that, if more cut is taken at one revolution or stroke than at another, the one cut will be deeper than the other. They are likewise liable to jar or tremble, the only remedy for which is to grind away some of the cutting face or edge, making it narrower. For taking finishing cuts on cast iron, more top rake may be given to the tool than is employed to rough it out, unless the metal to be cut is very hard; else the metal will be found, upon inspection, to have numerous small holes on the face that has been cut, appearing as though it was very porous. This occurs because the tool has not cut keenly enough, and has broken the grain of the metal out a little in advance of the cut, in consequence of an undue pressure sustained by the metal at the moment of its being severed by the tool-edge. For small wrought-iron, steel, or copper work, the tool shown in Fig. 2721 possesses the proper elements of shape, being far preferable to the square-nosed tools, since such tools do not cut the tough or fibrous metals true, but follow the texture of the metal, cutting deepest into the softest parts, especially when the tool-edge becomes dulled from use.

All tools should be fastened or held so that their cutting edges are as near the tool-post as possible, so as to avoid their springing, and to check as far as possible their giving way to the cut, in consequence of the play there may be in the slides of the tool-rest; but if, from the nature of the work to be performed, the tool must of necessity stand out far from the tool-post, we should give the tool but little top rake, and be sure not to place it above the horizontal centre of the work. The

tool most subservient to spring is the parting or grooving tool shown in Fig. 2723, which, having a square nose and a broad cutting surface placed parallel to the depth of the cut, and requiring at times to be slight in body, combines all the elements which predispose a tool to spring; to obviate which, it should be placed at or a little below the centre, if used in a lathe under disadvantageous conditions. The point at *C* is made thicker than the width at *D*, to give clearance to the sides, so that it will only cut at the end; and the breadth is left deeper than the width of the body of the tool-steel, to compensate in some measure for the lack of substance in the thickness.

The spring-tool shown in Fig. 2724 is specially adapted to finishing sweeps or curves, and may be used on either wrought or cast iron, or brass; the only difference in shape required to fit it for such various uses is to give it less top rake for cast than for wrought iron, and less for brass than for either. The fulcrum off which it springs is at the point *A*, because that is the weakest part (since the cutting edge, *B*, is at a leverage to *A*); the line of spring of the edge *B* is therefore in the direction

2724.



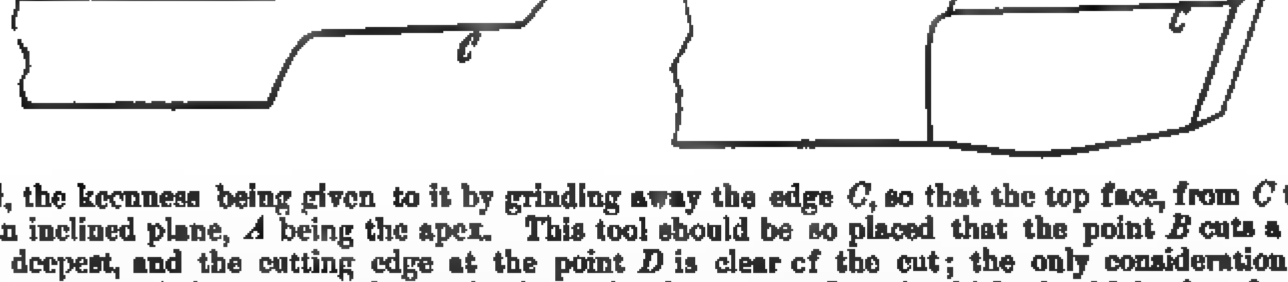
of the arrow *C*, which is away from its cut, so that it will give way to the metal rather than spring into it, which causes it to recede from the harder and spring into the softer parts of the metal, rendering its use unadvisable except for finishing curves, which it will do more smoothly and cleanly than any other tool, especially when necessity compels it to be held far out from the tool-post.

Side tools for use on iron, steel, or copper are subject to all the principles already explained as governing the use and shapes of front tools, and differ from them only in that the cutting end of the tool is bent around to enable the cutting edge to operate upon a face of the work which stands at a right angle to the parallel cut. A front tool is used to carry the straight cut nearly up to the shoulder; then a side tool is introduced to take out the corner and cut the side face.

A side tool whose cutting end is bent to the left, as in Fig. 2725, is called a left-handed side tool; and one which is bent to the right, a right-handed side tool. The cutting edges should form an acute angle, so that, when the point of the tool is cutting out a corner, either the point only or one edge is cutting at a time; for if both of the edges cut at once, the strain upon the tool causes it to spring in. For heavy work it may be made more round nosed, and allowed to cut all round the curve, and with a coarse feed. It is also an excellent tool for roughing out sweeps or curves; and for small short bolts it may be used on the parallel part as well as under the head. For taking out a corner or fillet in slight work, which is liable to spring from the pressure of the cut, the point must be rounded very little, and the fillet be shaped by operating the straight and cross feed of the lathe. It is made right- or left-handed by bending it in the required direction, that shown being a left-handed one. This form of side tool is that most desirable for all small work where it can be got in; and in the event of a side face being very hard, it possesses the advantage that the point of the tool may be made to enter the metal first and beneath the hard skin, causing it to break away from the pressure of the cut.

For cutting down side faces where there is but little room for the tool to pass, the tool shown in Fig. 2726 is used, *A* being the cutting edge. Not much clearance is required on the side of this

2726.



tool, the keenness being given to it by grinding away the edge *C*, so that the top face, from *C* to *A*, is an inclined plane, *A* being the apex. This tool should be so placed that the point *B* cuts a little the deepest, and the cutting edge at the point *D* is clear of the cut; the only consideration with reference to it is how much rake to give it on the face, from *C* to *A*, which should be less for cast iron than for wrought iron, and more when the metal is soft than when it is hard. Its spring does not affect it to any degree, since it springs vertically and in a line with the face of the cut, and not laterally and into it.

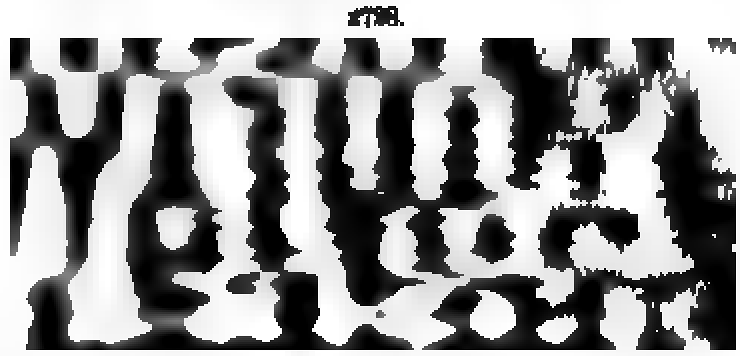
Turning Tools for Brass.—The main distinction between tools for use on iron or steel, and those for use on brass work, is that the latter do not require any top rake (unless the brass contains an unusually large proportion of copper). Fig. 2727 presents a front tool for brass, which possesses every qualification for all plain outside work, both for roughing out and finishing. For very light

work, or when the tool must be held far out from the tool-post, it may be given a little more rake on the bottom or side faces; while for finishing, the point may be more rounded and used with a coarser feed, providing the tool is rigid and not liable to spring. When held far out from the tool-post, the side faces may be ground keener, and the top face have negative top rake; that is to say, some of the rake may be ground off the top face, and more given to the bottom or side faces. Under such conditions, also, the cutting surface on the point of the tool may be reduced as small as convenient, so as to avoid the liability to spring. Ground round-nosed and smoothed with an oil-stone, this tool gives a true and excellent finish to plain work.

2727.

The best side tool for brass is that shown in Fig. 2728. It requires little or no top rake, and but little side or bottom rake, unless used upon very slight work, or used under conditions rendering it liable to spring. For taking out corners, and for turning out recesses which do not pass entirely through the metal, it has no equal. When it is held far out from the tool-post, it should have the top face beveled off, at an angle of which the cutting part is the lowest, which will thus prevent it from jarring or chattering, and from springing into the work. In grinding it, grind only the end (rounding off the corner slightly), so as to preserve the bend upon the end of the tool, which is placed there to give it clearance. It will take a parallel cut equally as well as a side one, and for small work can be used to advantage for both purposes.

2728.



Lathe-Tool Holders are appliances used to support the tool when it requires to stand far out from the tool-post, the size and strength of the holder being much greater than of the tool. For small work a tool-holder is often employed, the object being to save the forging of the tools by securing a short piece of rod-steel in the holder at the requisite angle to use the edges at the end face of the steel as the cutting edges. The slot in the tool-holder being at the requisite angle, the tool is always

2729.

2730.

presented to the work having a correct angle for ordinary purposes. Figs. 2729 and 2730 represent tool-holders for small work. Fig. 2731 is a tool-holder for heavy external work, and Fig. 2732 for internal duty. It is obvious that the end *B* is made to enter and be fastened in the tool-post.

Cutting Speeds of Turning Tools.—The cutting speeds most advantageous for turning metals depends in a great measure upon the lengths of the cut. The principle adopted for cast iron by William Sellers & Co., in the feeds of their planers and cylinder-boring machines, is undoubtedly the correct one. The theory of this principle is that, by taking a light finishing cut under a very coarse

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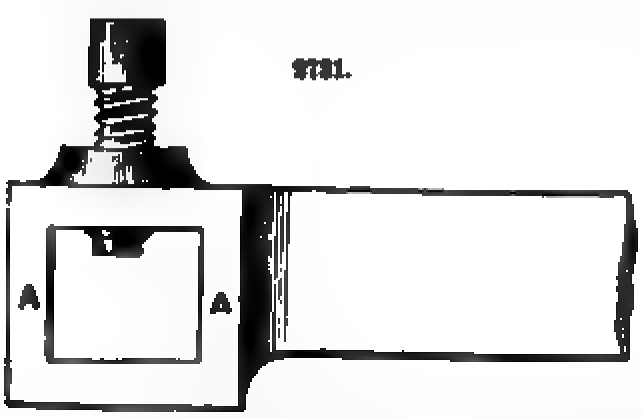

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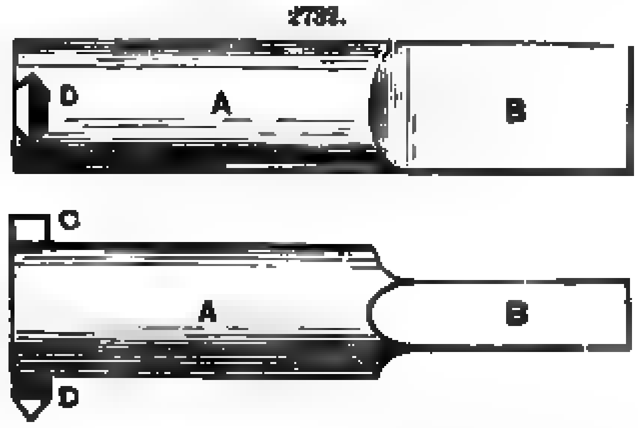


feed, with the cutting edge of the tool ground flat so as to leave the surface of the work level, the edge of the tool is under cutting duty during a minimum of time, and hence preserves its cutting edge longer in proportion to the duty. And since the cutting edge is better preserved, it follows that the finished work will be more nearly parallel. This principle applies more particularly to cast iron than to wrought iron or steel, because there is less strain in severing that metal. In planing machines the speed usually varies between 15 and 18 feet of cut per minute, and the feed for the first cuts is from 10 to 20 traverses of the work to an inch of tool travel; but for finishing cuts the tool travel is increased to from one eighth to one-half inch per cutting traverse of the work, the broader

cuts being taken upon the larger sizes of work. In turning wrought iron, steel, or brass work, the same principle holds good, but in a minor degree. Under all ordinary circumstances a maximum of tool-feed rather than of lathe-speed will perform the greatest quantity of work in a given time.

Power required for Lathe-Tools.—Dr. Hartig has determined that the power required for turning off metals is greater for small diameters than for larger ones. He gives the following formulæ, in which P represents horse-power and W the weight of metal removed per hour in pounds:

Turning cast iron	$P = .0314\ W$
" wrought iron	$P = .0327\ W$
" steel	$P = .047\ W$

The power required to drive ordinary cutting tools when empty varies for lathes with the number of shafts between the driving-shaft and the main spindle. In the following formulæ n represents the number of shafts between the driving-shaft and the main spindle:

No. of Intermediate Shafts.	Light Lathes, Empty.	Heavy Lathes, Empty.
0	$P = .05 + .0005\ n$	$P = 0.25 + .0031\ n$
1 or 2	$P = .05 + .0012\ n$	$P = 0.25 + .058\ n$
3 or 4	$P = .05 + .05\ n$	$P = 0.25 + 0.18\ n$

J. R. (in part).

LAUNDER. See MILLS (GOLD, SILVER, ETC.).

LAUNDRY MACHINERY. The process of laundering as now practised in this country differs materially from the methods formerly employed; boiling of the fabrics, hand-rubbing, and friction-ironing having been entirely superseded by various ingeniously contrived machines. The process is divided into four departments—bleaching, washing, starching, and ironing.

BLEACHING.—The bleaching process is required more particularly for new work. Its object is to whiten the goods, and also to remove any traces of oil which may have adhered to the fabric during the process of manufacture. This is accomplished by soaking the articles for a variable length of time in a solution composed chiefly of chloride of lime and caustic soda, thoroughly incorporated with a large quantity of water. After having remained in the lye solution for a sufficient period, the articles are dipped in the "sour," which is a solution made from oil of vitriol and water. This solution neutralizes and removes all trace of the alkali. Both of the bleaching solutions are made quite weak, so as not to injure the fabric submitted to their action.

WASHING.—*Power-washing Machines.*—There are three principal types of washing machines, the employment of each being determined by the class of goods to be washed. In collar and cuff laundries the *dash-wheel*, Fig. 2733, is considered the most efficient. It consists of a stationary cylindrical case, having in its interior a wheel divided into four compartments and hung upon a horizontal shaft. The wheel is either made water-tight or perforated. The former construction is preferred when small articles, and the latter when large goods, are to be washed.

The wheel is generally one foot smaller in diameter than the inclosing cylinder. For small work it measures usually 6 ft. 6 in. in diameter and 2 ft. 6 in. in depth; for large articles the diameter of the wheel is from 7 to 8 ft. Motion is imparted to the wheel by bevel-gearing. The speed of the wheel is from 20 to 22 revolutions a minute. Water is admitted into the stationary cylinder in a quantity sufficient to rise about 2 in. above the bottom of the wheel. When ready for washing, the goods are put into the different compartments of the wheel with a weighed amount of soap, the doors are closed, and the wheel is set in motion. By the revolution of the wheel the goods, constantly falling, are subjected to sudden impacts with the water, by which means the dirt is loosened and removed. The water is heated and kept almost at the boiling point by the admission of live steam. The time required in laundering new work with this machine is about four hours, but a somewhat longer period is usually given for the larger articles of wearing apparel.

In the *Brown washer*, Fig 2734, the method of washing is similar to that of the dash-wheel, in that the goods are subjected to continuous falls. This machine, however, accomplishes its work by violently agitating the articles within its cylinders. The dotted lines in Fig. 2734 show the way the cylinders are divided. It will be readily understood that the rapid revolution of the cylinders subjects the goods to a number of short falls, thus loosening the dirt as in the case of the dash-wheel; but it requires a somewhat longer time. The cylinders have short shafts bolted to their sides and

geared to the driving-shaft. The capacity of the machine is about 700 dozen of collars and cuffs at a washing. The cylinders are 40 in. in diameter, and make from 60 to 65 revolutions a minute.

In Fig. 2735 is shown the *Nonpareil machine*, which is entirely different in principle from the machines above described. Four vibrating arms, depending from a horizontal cross-piece, are connected by cranks to the driving-shaft. These cranks are placed at different angles on the shaft, so as to give the arms a uniform motion by pairs. On the ends of the arms are the rubbing-boards. The machine is run at a speed which gives 440 strokes of the arms per minute. This rapid motion, combined with the positive action of the beaters, squeezes the goods between the inclined corrugated faces of the rubbing-boards and the body of the machine. The arrangement of cranks is such that while one pair of boards are squeezing the goods the other pair have receded, and the fabric is opening and reabsorbing the water. By the rubbing-boards the goods are rolled over and over until they are thoroughly washed. This machine is much used in hotels and large manufactories.

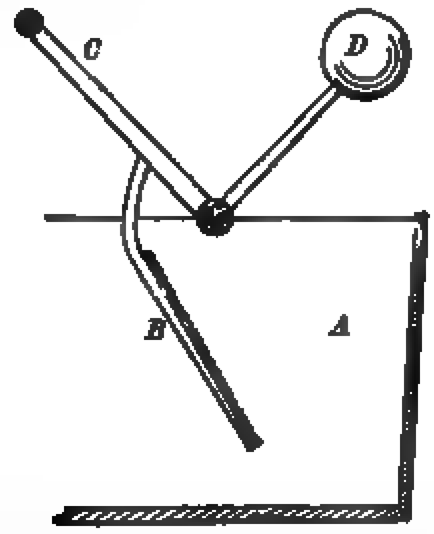
2735.

Hand-washing Machines.—The principle of rolling over or kneading the clothes has been applied successfully in the construction of hand-washing machines, better results having been obtained from apparatus thus constructed than from machines in which the fabric is compressed between rollers, the tendency of which is to cause wear of the articles and to crush buttons. The *Doty washing machine*, represented in Fig. 2736, consists of a water-tight case with a raised edge in which are placed the bearings on the handle. The wash-board is attached to the depending arm of the lever in such a way that the latter is easily moved. The clothes are placed in the case and by moving the lever up and down as in pumping they are thoroughly rubbed, squeezed, and lifted at each stroke. The action of the lever is aided by a compensating ball, as shown in Fig. 2737, in which *A* is the case, *B* the wash-board, *C* the lever-handle, and *D* the compensating ball.

To wash any fabric properly, it is of the utmost importance that the water be pure. Many extensive laundries have found it necessary to build large charcoal and gravel filters in order to render the water fit for use. Water that is very hard, containing large quantities of lime, will not properly

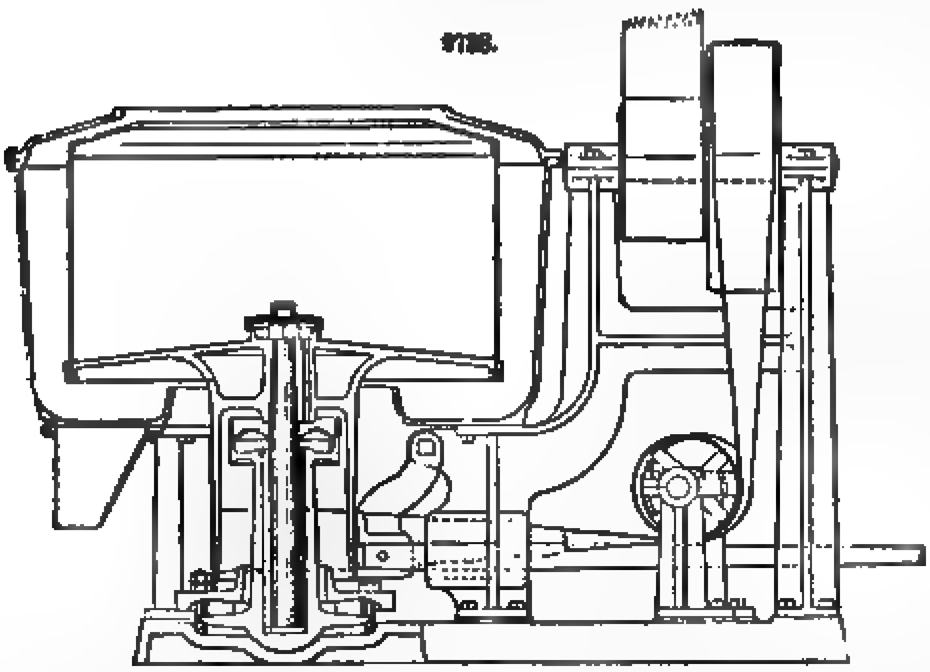
2736.

2737.



wash the goods, besides being injurious to the fabric. With regard to the soaps used, it may be noted that many which serve excellently for the household laundry are not suited for employment in connection with the machines. Those which have been found best adapted for extensive laundry work are manufactured from pure tallow and an alkali—in one case, caustic soda. Many of the soaps offered for laundry purposes are so loaded with rosin and the silicates as both to injure them and to render them unnecessarily expensive.

2738.



Wringing Machines. — After having been thoroughly washed, it is necessary that as much water as possible be extracted from the goods. The more perfectly this is accomplished, the better they will take the starch. Wringing is effected either by the hydro-extractor or by means of a power-wringing machine.

Fig. 2738 represents the *Tolhurst extractor*, which consists of a perforated copper basket inclosed in a cylindrical case. Motion is imparted to the basket at the rate of 1,000 revolutions a minute by means of a perpendicular shaft driven by a corner-turned belt over two loose pulleys. The base of the shaft is expanded, and underneath it are placed three rubber balls, the object of which is to prevent tipping or wabbling as the revolutions of the basket are reduced and the basket is brought to rest. This machine will remove the water from almost any article, but is specially adapted for use in collar and cuff laundries.

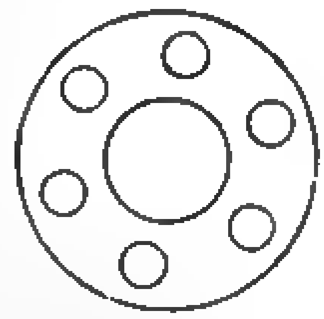
The *Universal wringer*, Fig. 2739, consists of two parallel rolls of vulcanized rubber fitted to shafts having at one end a double set of gears, which are arranged with long and strong alternate double sets of cogs on the same wheel. The arrangement of the cogs is shown in Fig. 2740, and is such that they cannot work laterally out of their places or bind. The rims between the teeth being of equal size, they roll easily when pressed together. The uppermost roller is set in loose boxes, upon which pressure is applied by means of a wooden spring, as shown in Fig. 2741. In attaching the rubber rolls to the iron shafts, considerable difficulty has been experienced from the fact that the sulphur of the rubber unites with the iron, rendering the metal porous

The rubber is also rapidly softened and destroyed. To obviate this difficulty, the shaft is first varnished, then wound with linen thread, after which several more coats of varnish are applied, and

2740. 2741.

finally the whole is covered with rubber cement. In the large sizes of the Novelty wringer, where great strain comes upon the rolls, they are perforated with holes for six lateral shafts, which fit into caps on each end of the main shaft. Fig. 2742 is a section of the roll. By this means any loosening of the rolls on the shaft is effectually prevented.

2742.



STARCHING.—*The Dipping Wheel.*—From the wringer the goods are taken to the dipping wheel. This consists of a cylindrical case hung upon a horizontal axis. The goods are put into this wheel with a certain amount of dipping starch, which is made by boiling wheat or corn starch and water together for 15 minutes, and adding an exact amount of aniline or ultramarine blue, the latter being preferred for shirts. The method of preparing the bluing differs in various laundries. It is rather an odd fact that goods are blued to suit the whims of various consumers in different sections of the country. Thus new collars, cuffs, etc., for a southern market are made of a tinge different from those intended for a western market, the hues running through changes of yellow, green, and blue. The names of the chemicals used for this purpose are trade secrets, as each firm have special receipts of their own. The starch used should be of the best possible quality. Corn starch is considered preferable, not only as containing more starch and less water and gum, but also for sanitary reasons. Fermented starch is always liable to a refermentation, and therefore is not only deleterious to health, but also destructive to the fabric to which it is applied Pure chemical starch gives the best results The starch chiefly used in the great laundries of Troy, N. Y., is that made by the Glen Cove Starch Company. This, by chemical analysis, gives the following composition: Starch, 85.62; moisture, 14.11; ash, .26; total, 99.99. The material contains no putrescible or poisonous substance, and is exceedingly pure. The goods are left in the dipping wheel for 15 minutes, which time, as the wheel revolves very rapidly, is sufficient thoroughly to incorporate the starch with the fabric. From the wheel the goods are sent to the rubbing or forming room.

The term "forming" is applied to a process in which a second quality of starch is thoroughly rubbed into the texture of the article, the object being to remove all wrinkles and straighten out the material, so to speak, into the proper shape for ironing. The starch used for this process is boiled for one hour, the bluing (generally aniline) being mixed with it. Forming is performed either by machines or by hand.

Starching Machines.—Fig. 2743 represents the Oakley & Keating starcher. It consists of an iron framework supporting a horizontal shaft with double cranks, which actuate with a reciprocating motion two arms having corrugated rubbing faces, working vertically in the starching box, which contains the rubbing starch. The goods being inserted between the arms, the motion of the faces rubs in the starch. The goods have then to be finished by hand, as no machine as yet invented completely accomplishes the object desired. As soon as the goods are formed, they are hung upon frames supported on iron ways, and are taken into a steam-drying room. When dry, they are removed and dampened, either by being sprinkled, or, in the case of collars and cuffs, by being rolled in wet sheets and left for one hour, when they are packed in boxes and sent to the ironing room.

IRONING.—*Mangles.*—The domestic mangle, Fig. 2744, consists of two parallel rolls of hard wood run by suitable gear. The upper roll is fitted with loose boxes, and the required pressure is regulated by screws. These machines are used for sheets, blankets, and other large articles in which no starch is used.

There are three principal forms of hot mangles. In the mangle of the Troy Laundry Company, the heat is supplied to the rollers by the combustion of gas within the ironing roller. The apparatus consists of an iron framework supporting a revolving ironing roller, 6 inches in diameter, immediately under and in contact with which is a drum covered with felting. The drum and ironing roller revolve at the same rate of speed. A small blower is set in the framework, and is used to supply the air which mixes with the gas. By means of a compound lever much or little pressure can be exerted upon the drum, depending upon the quality of the articles passing through the machine. Where polish is desired, the ironing roller is made to revolve faster than the drum, by changing the size of the gear-wheels. The capacity of this machine is 2,000 table-cloths or 10,000 napkins a day.

The French steam mangle, Fig. 2745, is composed of a steam-chest *A* and a revolving cylinder *B*. Steam is admitted at *E*, the exhaust passing off at *F*. *D* is a gauge-screw, which is used to regulate the pressure, the cylinder being fitted with loose boxes. The speed of the cylinder is regulated by the beveled gearing at *C*. This machine does its work by compressing the goods between the cylinder and the steam-chest. The rate of speed is low. The cylinder has two jackets of felting covered with muslin to absorb the moisture.

2745.

The third style of hot mangle consists either of a roller or stamping iron, in which a bar or block of metal is placed, which has been previously heated to redness. This style is little used, as the heat produced varies to such an extent as to render the ironing very uneven

Ironing Machines have been constructed under all three of the principles mentioned. Experience has proved, however, that gas is best adapted to the conditions required, and is less expensive.

Fig. 2746 represents the Wiles & Adams ironing machine, which consists of two pairs of revolving drums and ironing rollers, supported in an iron framework and connected with suitable gears. Collars, cuffs, and other articles of cloth, generally have one side which must present a nicely finished ironed surface, while the other side need not be thus finished. In practice the best finished surface is produced by the last ironing roller to which the articles are subjected. In this machine the articles are first introduced by hand and in a damp condition between the first set of rollers, *B C*, Fig. 2747, and are thereby considerably dried, and gen-

erally ironed sufficiently on one side. They are thence directed by the guide and conducted by the feeding device—which consists of an endless apron made of linen warp with fine cane run through it, revolving from front backward —over two geared rollers, so as to have the same surface-speed as the clothed drums. The fabric passes to the second set of rollers, *D E*, which finish the drying of the articles and iron the other side completely, discharging them upon an apron or table. It is important that the most highly finished surface should be uppermost when leaving the machine, so that the attendant can detect imperfections, and repass the article if necessary between the last set of ironing and clothed rollers only. To secure this result, the machine is so arranged that the first set of rollers with the clothed roller *C* is over the ironing roller *B*, and the second and last set of rollers with the ironing roller *D* over the clothed roller *E*, and an open feeding-in space *J* is provided between the roller *D* and the roller *C*. The two clothed rollers *C* and *E* are connected together and to the driving-shaft by a set of gearing, so as to be positively turned with substantially equal surface-speed by that shaft; and the two ironing rollers *B* and *D* are geared with the same driving-shaft by another and separate train of wheels, which communicate substantially equal surface-speed to the ironing rollers. The surface-speed of the clothed rollers is about 3.6 per cent. faster than that of the ironing rollers.

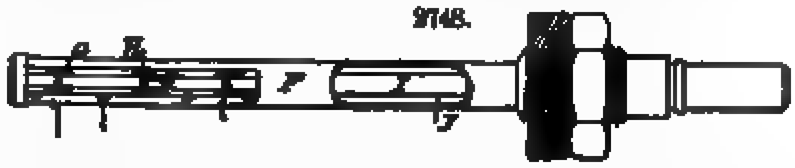
2747

By thus connecting the two clothed rollers *C E* with the driving-shaft by one set c changeable, and also connecting rollers *B D* with the same driving-s and separate set of gearing also m the surface-speed of the clothed rol ily altered, so that they are turned rate of speed suitable for ironing cles, or at different faster rates as necessary in ironing various thinn this is done without altering the sp ing-shaft; and at the same time tl of the ironing rollers can be chang will be turned either with the sam as the clothed rollers to give a lust tic finish, or to a faster speed to p ironed surface on one or both side Higher finish on one side of the the other is effected by the greater during the passage through the last by means of compound levers. The strain exerted on the first pair is about 200 lbs., and on the last pair 2,000 lbs. Upon the lever is the seat *R*. The weight of the person feeding the articles causes or assists in pressing the clothed roller *E* against the ironing roller *D*, with a yielding force that is necessary in ironing the articles. Hence, when the person stops feeding and gets off the platform, the pressure is removed and the rollers are separated.

The ironing rollers *B D* are constructed of cast iron and made hollow, and are heated internally by a mixture of gas and air. The principle of the burner, Fig. 2748, is that of the Bunsen burner slightly modified. Fig. 2749 is a section of the burner, which is placed within the ironing roller and is stationary. At one end of the roller is situated a pipe, which

conveys to the chimney the products of combustion. The burner itself consists of a cylindrical tube *F*, Fig. 2748, which contains the tube *I*. The gas and air admixture (gas one part, air ten parts) is brought to the tube *I* by rubber tubing having gauge-cocks to provide for regulating the amount of admixture. At *G G* are orifices in the tube *I*, where ignition takes place. With the ordinary burner it is found that in tubes of a small diameter combustion of the gaseous compound is not entire, owing to a deficient supply of oxygen. The consequence is, that

2748.



the inside of the ironing roller soon becomes covered with soot, which not only prevents the heating of the roller, but also sifts out over the goods during their passage through the machine. To obviate this difficulty, a current of pure air is forced by means of a small blower through the inside of the tube *F*, in the space *J*, outlets *H* being provided immediately in apposition to the gas outlets *G*. By this arrangement good combustion is secured, and the perfect heating of the ironing rollers is the result.

2749.

In ironing machines made with an ironing roller turning against a clothed roller, the water or moisture that is driven out hot from damp articles is absorbed by the fibrous covering, so that the latter becomes quite wet. To prevent oxidizing the metal of which the drum is made, a layer of three-sixteenths of an inch of vulcanized rubber is first laid over the metal. In order to lessen the heating of the rubber, the body of the roller is made in the form of a thin metallic shell more or less open at the ends. The rubber is surrounded by three jackets of felting, in all one-fourth of an inch in thickness. Over this are wound 5 yards of canton flannel and 10 yards of muslin; the whole is secured by recesses in the cylinder and tightly fitting clamping-

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2753.

rings. The speed of the rollers in ordinary work is about 6 revolutions a minute, and their capacity is 1,000 dozen of collars and cuffs a day.

Fig. 2750 represents a collar-finishing machine. Many of the collars worn at the present day have points which are turned down; and as the process of turning down brings that side of the collar into view which has the less highly finished surface, it is necessary to re-iron the under side of the points

The machine used consists of a plunger-iron heated by the gas-burner, as described in the Wiles machine. Under the plunger and over the bed passes a belt of felting to absorb the moisture, and the plunger is lifted and brought down by pitmans fastened to the crank-pin. The belting is rotated by a beveled gearing moving the length of the bed at each lift of the plunger.

The edge is raised on collars and cuffs by means of the machine shown in Fig. 2751, consisting of two cold narrow steel rolls, between which the article is passed.

Fluting is accomplished either by pressing the articles between a fluted sadiron and similarly fluted base-plate, or by passing the material between fluted parallel rollers, as shown in Fig. 2752.

The irons used for pressing the edges of turn-down collars are made in the shape shown in Fig. 2753. Where a polish is desired, Japanese wax is lightly rubbed on the surface of the articles.

Fig. 2754 is the laundry heater, used for warming irons for hand-finishing. The fire-pot or body of the stove has concentric rings around the outside, on which the irons rest. The fire-pot is in the shape of an inverted funnel, and is kept filled to the top of the upper door. The irons are kept immediately in contact with the portion in which the greatest amount of heat is generated. In summer the outside doors can be closed, allowing the heat which would otherwise be sent out into the room to pass up the chimney. As a strong fire is required, the ash-pit and under air-space are made large. G. H. B.

LAWN-MOWER. See Agricultural Machinery.

LAY. See Looms.

LEAD FURNACES. See Furnaces, Metallurgical.

LEAD PENCILS, MANUFACTURE OF. This is the most important industrial application of graphite. (See Graphite.) The first operation is the grinding of the mineral in cannon-ball mills (see Mills, Grinding), after which the graphite is washed. The washing process is conducted in four casks, which are arranged on a series of successively higher platforms. The graphite is placed in the uppermost cask, with water, in which the particles arrange themselves according to their weight, the lightest and finest being nearest the surface. These are drawn off through a spigot, about one-third down from the top, into a second cask or vat, where the same rearrangement takes place; the finer portions are drawn off into the third, and finally into the fourth vat, so that in each of the four receptacles is graphite of different degrees of fineness. When the graphite contains lime and alkaline impurities, these are removed by acids; and in general it is so treated chemically as to remove any foreign mineral substances. The clay with which the graphite is subsequently mixed comes chiefly from Bavaria; it is blue in color and of extremely fine grain. This is also washed in a series of vats as above described. For pencils of the finest quality, graphite from the last washing vat is employed; for inferior grades, it is taken from the other vats, the coarsest material entering into the manufacture of the lowest grade of pencil. The clay and powdered graphite, on being mingled with water, are ground in paint mills, whence the compound emerges in a pasty condition. The quantity of clay added depends on the desired degree of hardness of the pencil, the greater proportion of clay entering into the harder leads. The paste is next placed in a bag-press similar to that used for expressing oil from cotton or linseed; and the water being thus squeezed out, the material emerges in a thick plastic mass. This is placed in the metal cylinder of another press, in which cylinder, above the graphite, is a follower which is pressed down by mechanism from above. In the bottom of the cylinder is an aperture, the shape and dimensions of which depend upon the diameter and form of transverse section to be given to the finished lead. The mass under the heavy pressure spins out from this aperture like a thread, and is deposited on a board placed beneath the cylinder for its reception. When a sufficient quantity has thus been expressed, it is removed. The filaments are straightened and dried on flat boards, and are then placed in formers and cut to the desired length, about 7 inches. The leads, 40 gross at a time, are next packed in square crucibles and subjected to a white heat for about three hours, the time depending on the quantity of clay entering into their composition. They emerge hard, resonant, and rather brittle, and are ready for insertion into the wooden cases or coverings. The wood used for the latter is red cedar, and the supply for the entire world comes from Florida. It is there sawed to exact size in thin slabs 7 in. long by 2¼ in. in breadth. On reaching the factory they are kiln-dried, and in some cases stained a darker color. The first process which the wood undergoes is planing and grooving. This is done by an ingenious special machine, which planes the side, and at the same time cuts six narrow parallel grooves therein. The slab is then ready to form a longitudinal half of six pencils, and two slabs joined grooved face to grooved face (the leads being inserted in the grooves), when cut in the manner hereafter described, form the six complete pencils. The insertion of the leads and gluing of the faces is done by a series of workmen. No. 1 inserts the leads; No. 2 applies the glue to the faces; No. 3 places the latter together; and No. 4 inserts the slabs, many at a time, in a screw press, where they are subjected to powerful pressure and left to dry for 24 hours.

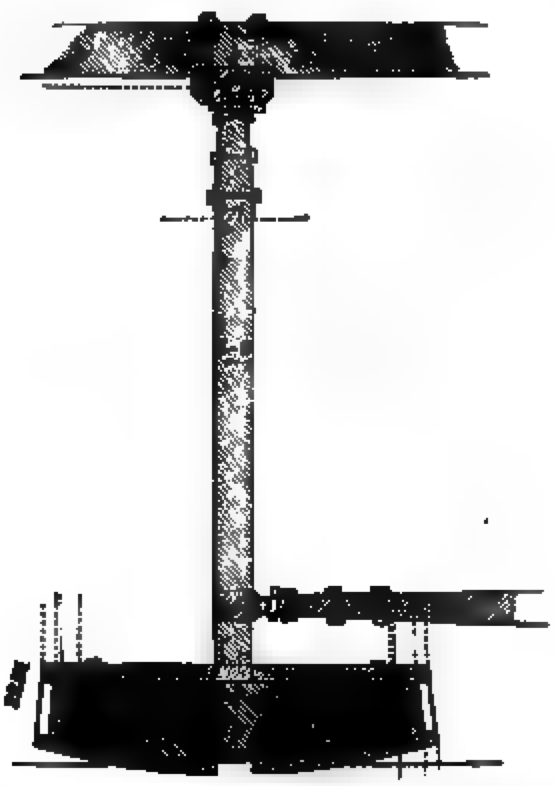
The next process is the dividing of the slab into individual pencils. This is simply done by a series of cutters, which cut the pencils apart longitudinally, and at the same time give them a cylindrical or polyangular form. The machines for coloring the pencils are admirably adapted to replace hand-labor. The pencils are placed in a large hopper, from which they fall one by one upon rollers, between which they are grasped and pushed rapidly through a vessel containing the stain. On emerging from the latter, they fall upon a long endless belt; and while being carried along this they are dried, and fall into a receptacle placed at the end of the belt. Varnishing is done in a similar manner, and polishing by passing between smooth metal rollers. The ends are then cut by an ingenious contrivance, leaving the pencils exactly of a length. Nothing further remains to be done but to apply to the pencils the gilt stamp denoting grade, maker's name, etc., and pack them in bundles for the market.

The "leads" of red and blue pencils are composed simply of clay and coloring matter, prepared in shape while plastic as above described, and subsequently boiled in stearine or wax.

LEATHER-WORKING MACHINERY. A large number of special machines are used in the preparation of leather, the majority supplanting hand-labor. One of the most important, as well as one of the first through which the hide passes, is

The Hide Mill.—This is a large wooden drum or cylinder about 8 ft. in diameter and 4 ft. in height, water-tight, and having large wooden pins projecting radially from the interior concave surface toward its horizontal shaft. Near one end of the drum, and exterior to it, is a small iron pinion, whose shaft is parallel to the shaft of the cylinder, which engages the cogs upon the circumference of the drum, causing it to revolve from 8 to 10 times per minute. The pinion-shaft is put in motion by a belt connected with shafting. The mill is used for stuffing light leather and for various other purposes.

2755.



After stoning, skiving, and shaving, the sides are quite hard, and are put in the mill with some tan liquor to soften them and to make them porous. In stuffing, a charge of about 20 sides, more or less, is put into the mill, with the proper amount of dubbing, and it is then set in motion for 15 or 20 minutes, when the milling is completed.

For softening leather, instead of the device above described, a mill of the form shown in section in Fig. 2755 and in plan in Fig. 2756 is often used. It consists of a strong wooden box, with curved bottom and ends, as shown. An opening is provided at the centre for the escape of the surplus water. The hides are worked by two plungers or hammers, which are reciprocated by the double crank shown. A mill of this form, of ordinary capacity, softens about 100,000 hides yearly.

Fleshing Machines.—Fig. 2757 represents an ingenious machine for removing flesh from hides, thus supplanting the fleshing-knife in the hands of the currier. The hides are placed on the curved bed, and the flesh is removed by the revolving blades *b*. These are of glass, with rounded edges, and have a slight play in order to accommodate themselves to varying thicknesses of hide. They are held up to their work by spiral springs *s*. A new form of fleshing machine, exhibited at the Paris Exposition of 1878 by M. Tourin, is illustrated in Fig. 2758. Its essential feature is the wheel *B*, made of curved pieces of steel alternated with pieces of wood, which operates upon the surface of the skin beneath it. This wheel is adjusted to heights to suit varying thicknesses of skin by means of the lever *A*. The hide is clamped in place, and the table has a to-and-fro motion from left to right and back under the roller, so that all portions of the hide may thus be brought under the action of the latter. The speed of the roller is 98 turns per minute. The motive power required for the machine is 1 horse, and its claimed capaci y is 50 hides or 80 to 100 sides per day.

2757. 1

The Rocker.—After fleshing, the hides are ready for the tan-pit, and here they are hung on a frame called a rocker, which is slowly moved by machinery, the oscillation being over about 6 inches, thus causing as little agitation to the liquor as is consistent with a gentle movement of the fibre of the green stock. Fig. 2759 represents an improved form of rocker.

In order to transfer hides from one vat to another, *reels* are used, consisting of four-sided frames of bars placed parallel and rotated by a crank on a horizontal axle. The reel and its standards are

2758.

not fastened to the floor, and may be placed between any two pits as required. The hides being attached together are led up from one pit over the reel and into the adjacent pit, and by turning the reel they are lifted and transferred. The facility with which packs may be thus transferred from one vat to another commends this skeleton reel to all tanners. It is safe to estimate the performance of this machine with two men as equal to that of six men by the old hand process. Besides, it does not require either man to stoop in his work, and the labor is therefore much easier. The stand and skeleton drum should be made of as light material as possible, so that its transfer from one vat to another may be effected by the two men with ease.

Scouring Machines.—The processes of hand scouring done mechanically by these machines will be found described under LEATHER-WORKING TOOLS. *The Burdon scourer*, Fig. 2760, is mainly employed for scouring on the grain, removing bloom, and softening and cleans-

ing the hide. It is especially applicable to harness, calf, sheep, and goat leather. Another form of apparatus for scouring, known as the *Lockwood machine*, is represented in Fig. 2761. This can be set at any angle with the line of shafting, and belted on either end from above or below. From 1 to 3 horse-power is required to run it, according to the thickness of leather being dressed. It is almost automatic in its movements, and is capable of a wide range of work, from the lightest to the heaviest. It scours, sets out, or glasses, and can be made to take a slow or quick stroke, a long or a short one, this last being effected by the epicycle and cam combined.

Slicking Machine.—The machine represented in Fig. 2762 is of French construction. It has a belt *B* passing over the pulleys *C*, and to this belt are attached the slickers. For coarse work these are of stone; for medium work copper is used, and for finishing, glass. The hide is stretched on

2762.

the table, which is moved by the attendant upon the tracks shown. The platform of the table has a to-and-fro motion on its supports, so that any portion of the hide can be presented to the slickers as may be desired. This machine slicks from 60 to 70 sides daily, and is easily managed by one man.

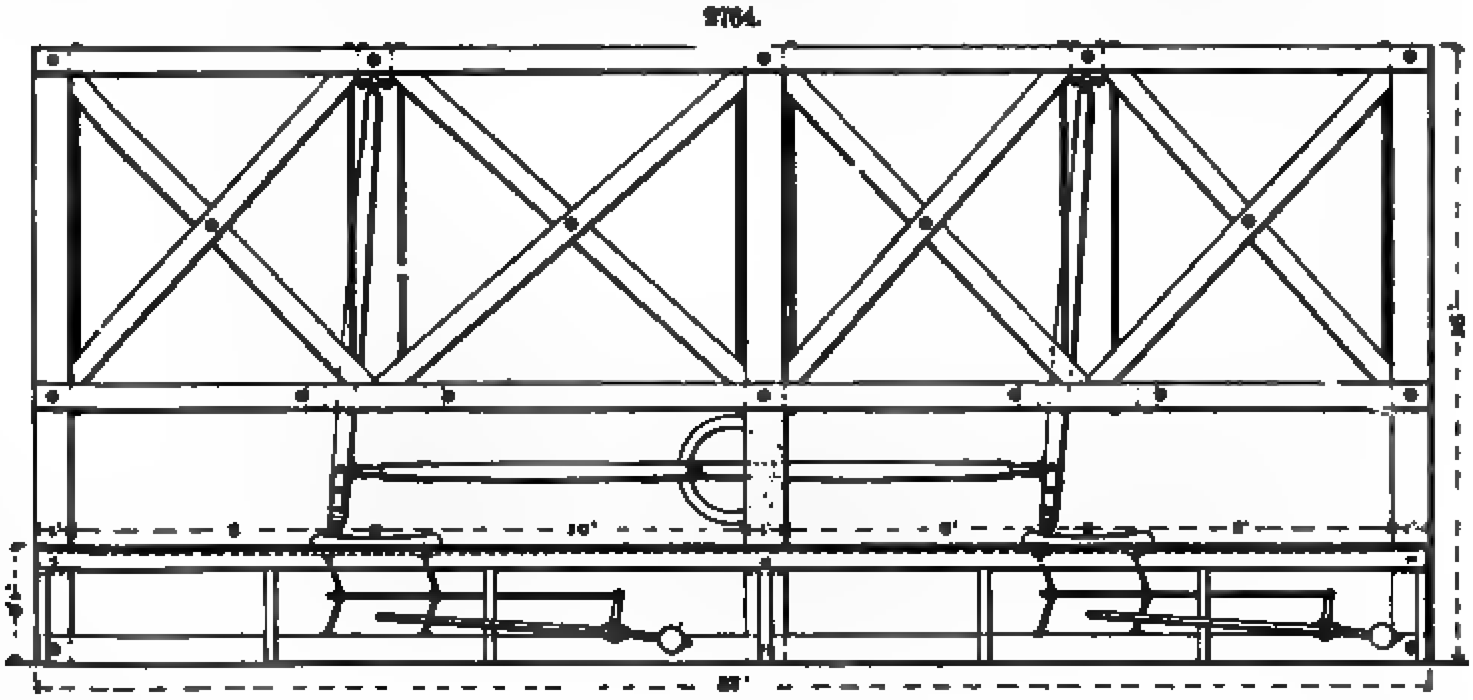
Graining Machine, Fig. 2763.—This apparatus takes the place of the graining board operated by

hand. *A* is the graining board, which is oscillated by the pitman from the large gear-wheel shown on the right. The most important feature of the machine is the table *B*, which is made of a series of separate pieces arranged side by side like the keys of a piano. These pieces are supported on

2763.

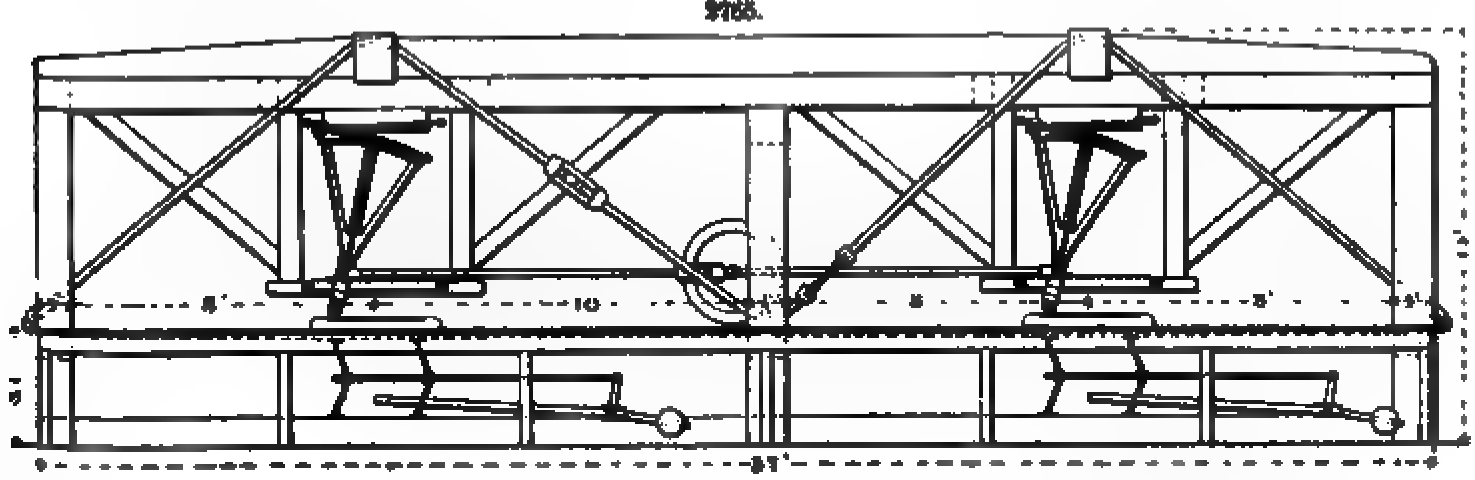
springs, which yield under the pressure of the graining board to an extent proportional to the thickness of the leather. By this means the apparatus is enabled to work upon thin or thick hides with equal facility. Its capacity is from 10 to 12 sides per hour. Motive power required, 1 horse.

2764.



Rolling and Hardening.—After being tanned, hides are dried and rolled to compress and harden them. Fig. 2764 shows the usual form of roller, the arm of which oscillates at about 100 double strokes per minute.

2765.



Another and better form of roller is shown in Fig. 2765. This has the advantage of not rolling the leather on a curved bed, and therefore does not tend to buckle the side.

Instead of being rolled, hides are sometimes hammered.

Whitening, Buffing, and Skiving Machine.—A machine of this class is represented in Fig. 2766, and is very simple in construction. The leather is acted upon by a cylinder which contains 32 knives or blades, inserted spirally. A sharpener is provided, which travels forward and backward across the edges of the blades. The cylinder revolves 2,780 times per minute, and the pendulum swings to and from the operator at a speed of 90 per minute. Power required, from 4 to 5 horse, according to the thickness of the leather.

Leather-Splitting Machine, Fig. 2767.—This apparatus is used for splitting hides, the skin being carried by the rollers against a long fixed blade. It may be operated by hand-power.

LEATHER-WORKING TOOLS—CURRYING. The various hand-tools used by curriers are illustrated in Figs. 2768 to 2773. Figs. 2768 and 2769 are *fleshing knives*, and are used to scrape off the hide and to remove adherent flesh, lime, and dirt. Fig. 2769 is a German flesher. The hide, while being fleshed, is placed on the convex surface of an inclined beam, which consists, first, of a heavy block of wood upon which the currier stands. Into one end of this block is mortised a stiff block of wood, faced with light wood and then with a plate of mahogany or lignum vitæ. The inclination of the beam, Fig. 2770, depends on the convenience of the operator, who holds the leather by pressing it against the beam with his legs and body. Fig. 2771 is a *moon-knife*, 10 or 12 in. in diameter, and having a 4- or 5-inch hole in the centre into which the hands of the operator are introduced. The knife is concave, presenting the form of a conical zone. The concave part is applied to the skin. The edge is turned over a little, to prevent it from entering too far into the leather. The *worker*, Fig. 2772, is a two-handled, blunt-edged knife, curved to suit the inclined rest of the beam-house, and used to scrape hides. A keen-edged knife is used in the beam-house to remove short hairs (new growth) from the hides. Fig. 2773 represents the *currier's knife*, which is double-edged, rectangular, about 12 in. in length and 5 in. in width, with a straight handle at one end and a cross-handle at the other, the axes of both being in the plane of the blade. The latter is a plate of steel carefully and peculiarly tempered, and is ground to a straight edge by rubbing it forward and back-

ward on the *rub-stone*, which is a block of sandstone placed on a strong trestle of convenient height. The upper surface should be a perfect plane. Rub-stones of Nova Scotia sandstone are cylindrical, about 8 in. in diameter by 1 ft. in length. The scratches left on the blade by the rub-stone are removed by rubbing on a fine Scotch or Welsh clearing-stone, which leaves a wire edge. The work-

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man then takes a *turning-steel*, and by rubbing it carefully from end to end turns the edge completely over. To keep the knife in this condition requires the greatest skill, as it cannot be used for more than a minute without losing its keenness. To restore this, the point of a small steel (finger-steel) is first run along the groove formed by turning the edge over, and then the steel is made to pass along outside the edge. When used, the plane of the knife-blade is held almost perpendicularly to the skin.

In the operation called *skiving*, the skin is laid over the beam, and the rough fleshy portion is shaved off by the currier driving his knife obliquely a few inches at a time, keeping the right-hand handle slightly in advance of the left-hand one in the downward motion. In *shaving*, the knife is driven from the top to the bottom of the beam, thus taking off slice after slice, removing all the inequalities left after skiving, and making the leather of uniform thickness, with a fine smooth face on the flesh side. *Flattening* is the same as shaving, except that in some cases the skin after skiving is shaved *across* (i. e., nearly at right angles to the skiving), and then flattened by being shaved again in the same direction as the skiving.

Stoning consists in forcibly driving the *stock-stone* over the leather, in order to stretch the material, remove inequalities, and render the grain smooth. The North River and Walpole scouring stones are generally used The stone is flat and rectangular, and is fixed to a handle. Its dimensions are about 6 in. in length and half an inch in thickness. *Slicking* consists in removing water and grease, scraping the leather, and eradicating the superfluous marks left by the stock-stone. The *steel slicker* used for this purpose is represented in Fig. 2774. It is a rectangular piece of steel about 5 in. long. The edge is also a rectangle, and is sharpened upon the rub-stone by grinding it perpendicularly and

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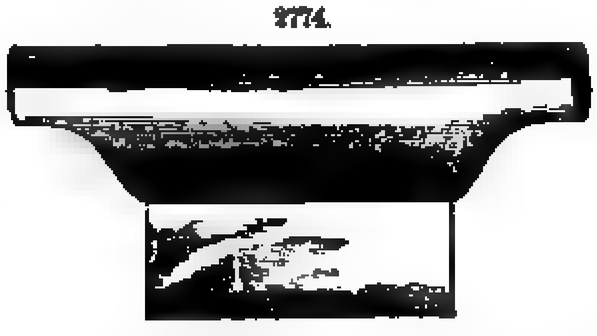

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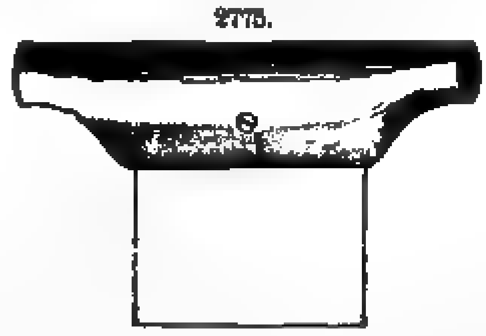


then upon each side. Slickers of glass or lignum vitæ have rounded edges, and are chiefly used to smooth out and polish leather. The *buffing slicker* differs from the others in having a narrower, longer, and very much thinner groove running along it, thus forming two very keen cutting edges, which are kept in proper condition by the finger-steel. It is used by placing one edge and the stock flat upon the leather, the latter being stretched upon the table, and forcibly pushing it forward, taking off thin shavings from the grain surface. When one edge is dulled, the slicker is turned over and the other side used until it loses its edge, when the finger-steel must again be brought into use.

Whitening taxes the skill of the currier perhaps more than any other operation. The leather is laid over the beam, and with an extremely fine-edged knife a thin shaving is taken from the flesh side. This may be performed by the *whitening slicker*, Fig. 2775, which differs from the *buffing slicker* only in having a very narrow rectangular edge. In this case the leather is placed on a table, and the slicker is laid flat upon it. The tool is then driven with great force repeatedly down the length of the side, taking off parallel and very thin shavings. The edges of the slicker must be so true that not a scratch shall appear on the surface of the leather. *Graining* consists in giving to the leather a granular appearance upon the grain side by either the *graining board* or pebbling machine. The graining board is a rectangular piece of wood with the upper surface plane. The lower surface is convex and fluted with grooves parallel to its length. A leather strap attaches it to the hand or arm. The grooves are coarse or fine as occasion requires. *Bruising* consists in doubling the grain side of a hide together and rubbing it on the flesh with a graining board. Doubling the leather with the flesh sides together, and driving the fold forward and drawing it backward by the graining board, is called *boarding*. Its object is to make the leather supple and raise the grain. A kind of graining board often employed is made of cork and has no grooves.

Scouring is done either on the flesh or on the grain. The *scouring table* is large and firmly built, and has a top usually of slate or marble. It is about 12 ft. long and 4 ft. wide, and is so constructed that the water used in scouring may pass off readily upon the side opposite to that on which the workman is engaged. In *scouring on the flesh*, the skins are spread out and set on the scouring table by passing a steel slicker over the flesh side, which brings the grain in close contact with the table, so that close adherence is caused. A bountiful supply of water is rubbed briskly over the flesh side with a stiff brush, and in this way the pulpy portions of the surface are scrubbed off. The skin then presents a soft whitened appearance. In *scouring on the grain*, the skin is set on a scouring table by a slicker which stretches it and at the same time loosens the *bloom*. This last is a yellowish deposit on the grain side derived from the bark in tanning. Its ease of removal depends on the nature of the water. The softer the water, the more readily can the bloom be removed. The grain side is kept uppermost, and is smartly brushed with a stiff hair-brush, using at the same time plenty of water, when the slicker is again used to remove the water and loosened bloom.

LEVER. See STATICS.

LEYDEN JAR. See ELECTRIC MACHINES, STATIC.

LICKER-IN. See COTTON-SPINNING MACHINERY.

LIFE-BOATS. Vessels constructed especially for the preservation of life in case of shipwreck.

Shore Life-Boats.—The qualities necessary to these craft, as summed by the Royal National Life-Boat Institution of Great Britain, are: 1, great lateral stability or resistance to upsetting; 2, speed against a heavy sea; 3, facility of launching or taking the shore; 4, immediate self-discharge of any water breaking over her; 5, self-righting if upset; 6, strength; 7, storage room for a large number of passengers.

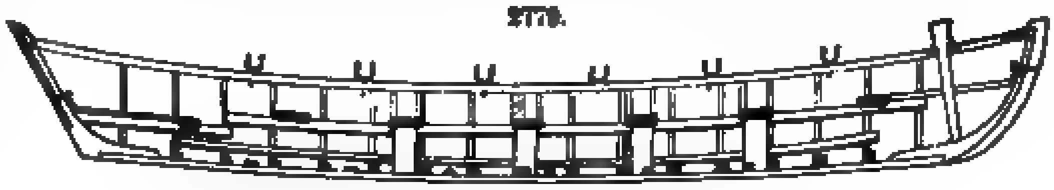
Figs. 2776, 2777, and 2778 represent in detail one of the most improved forms of English life-boats. Fig. 2776 represents the sheer plan, Fig. 2777 the deck plan. At *a* are the delivering tubes; *b*, air-cases; *c*, well; *d*, air-cases; *e*, empty air-cases under deck; *f*, fore air compartment; *g*, after air-compartment; *h*, air-cases; *k*, mast-thwart; and *s*, air-scuttles. Figs. 2779, 2780, and 2781 show respectively the sheer plan, deck plan, and cross-section of the American life-boat. This is an ordinary surf-boat of cedar, weighing about 700 lbs. The mode of conveying life-boats on carriages to the beach for launching is shown in Fig. 2782.

A number of the principal varieties of life-boats in use in England are represented in Figs. 2783 to 2794.* Fig. 2783 represents the North Country or improved Greathead plan, now nearly obsolete. These are the widest rowing life-boats in existence, some of them having as much as 10½ to 11 ft.

* From a paper by Charles H. Beloe, C. E., in *Scientific American*, xxxi., 12.

beam with a length of 30 ft. At *A* are air-tight compartments, and at *B* is a water-tight deck. Fig. 2784 represents a Norfolk and Suffolk sailing life-boat, which is of little value under oars. These boats measure from 39 to 46 ft. in length, and from 10½ to 12 ft. in breadth. Figs. 2785, 2789, and 2790 are plan and sections of a self-righting life-boat of the Royal National Life-boat Institution, similar to the one in Figs. 2776 to 2778. *A* represents the water-tight deck; *B*, the relieving tubes; *C*, the side air-cases; *D*, the end air-chambers; *E*, the ballast; *F*, scuttles to admit of a free current of air under the water-tight decks when the boat is ashore; *G*, another scuttle for air and to receive a pump. In the cross-section, Fig. 2785, *A* represents the sections of the side air-cases; *B*, the relieving tubes, of the same depth as the space between the decks and the boat's floor *C C*, Fig. 2790, are spaces beneath the deck, placed longitudinally at the midship part of the boat and filled with cases packed with cork forming part of the ballast; *D*, scuttle for ventilation, having a pump fixed in it, by which any leakage beneath the deck may be pumped out when afloat. The actual time occupied by one of these boats in freeing itself from water is about 30 seconds.

2789.



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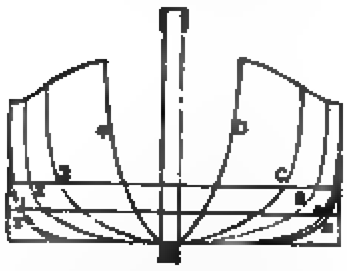

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Figs. 2791 and 2792 represent two boats built on the tubular principle. That shown in Fig. 2791 has a length over all of 40 ft.; diameter of tubes, 3 ft.; distance apart, 3 ft. 6 in. In Fig. 2792 the tubes, instead of being circular, are flat on the inner sides. Their ends are not brought together, but the inner sides remain parallel throughout, and have a sort of bow or cutwater at one end. The

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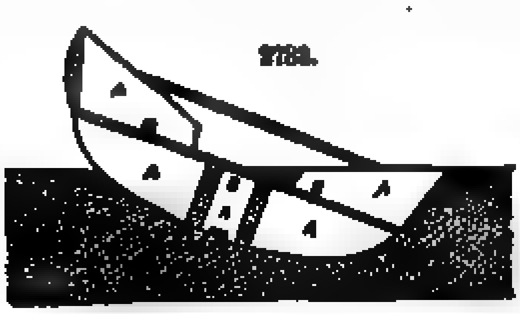

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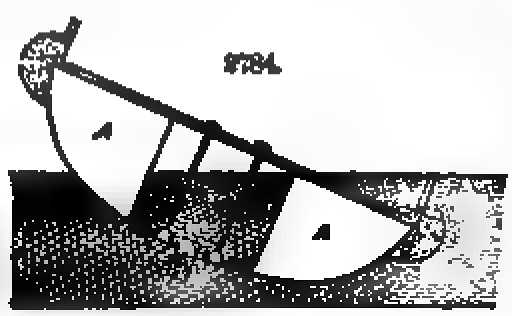

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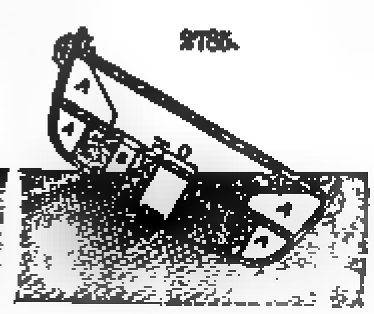

dimensions are as follows: Length, 36 ft.; breadth, 10 ft. 2 in. outside tubes, 9 ft. 8 in. outside gunwales; diameter of tubes, 3 ft.

Ships' Life-Boats.—The essential requirements of these boats are: 1, buoyancy sufficient to insure that the boat be manageable when, in addition to the number of persons and additional dead weight (if any) she is intended to carry, she is filled by a sea; 2, the fittings or appliances by which such buoyancy is obtained to remain sufficient under all circumstances of climate and temperature, as well

as under exposure to sun, weather, and salt water; 3, fitness for use as an ordinary ship's boat; 4, strength; 5, durability; 6, lateral stability, or resistance to upsetting on the broadside; 7, relief of water to the outside level; 8, cheapness; 9, simplicity of structure; 10, lightness. It will be seen at once how different are the conditions from those of a shore life-boat, and how the latter

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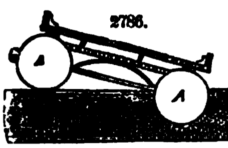

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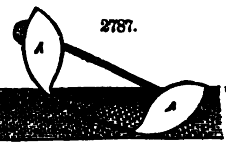

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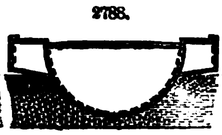

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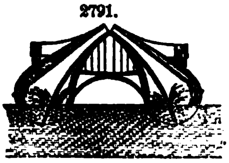

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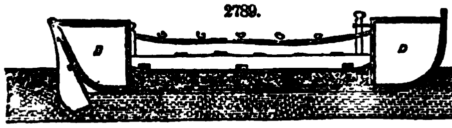

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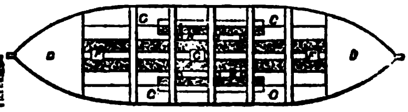

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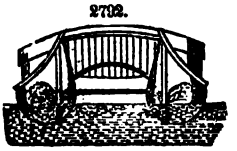

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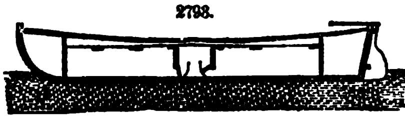

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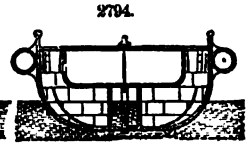


would fail to comply especially with requirements Nos. 3, 8, 9, and 10. Self-righting is not considered as essential; in fact, boats in an open sea are far less likely to be upset than in the heavy breakers near the shore.

Hamilton's life-boat, Fig. 2793, is 25 ft. long by 7 ft. beam, with the crew on board and the water admitted to the outside level. This boat has a freeboard of 20¼ in., and with 15 additional passengers the freeboard is reduced to 12 in. It is built of galvanized corrugated iron, and has special means for ejecting the water, as follows: The two plug-holes, 3 in. in diameter, are placed in the centre of the boat, and a water-tight bulkhead is fixed on each thwart on opposite sides of the plug-holes. Each of these bulkheads is furnished with a simple flap-valve opening inward. In the event of the boat shipping a sea, she is turned head to the wind; and as the bow rises to the waves, all the water contained in the fore part of the boat passes through the valve in the foremost bulkhead, but cannot pass the second one; consequently the water is heaped up in the space between the two bulkheads. As the bow falls again the valve closes, and the water of the centre will be higher than the outside level if the plugs have been left in; on withdrawing them, it will fall to the level of the sea. The same process is repeated as the stern rises, and a few movements of the boat are sufficient to free her from water, with the exception of about one inch at the bottom.

Lamb & White's life-boat, Fig. 2787, shown in cross-section, is built of two thicknesses of plank, with prepared water-proof material of an adhesive nature interposed.

Combe's cork and cane life-boat, Fig. 2794, is composed of two baskets placed one inside the other, and secured by a deep wooden keel, the space between the baskets being filled with cork. One great advantage of this form of construction is its lightness, a boat 25 ft. long, 8 ft. beam, and 3 ft. 4 in. deep weighing but one ton.

LIFE-PRESERVERS. The essential qualities of these devices are as follows: 1, sufficient extra buoyancy to support a man heavily clothed, with his head and shoulders above the water, or to enable him to support another person besides himself; 2, perfect flexibility, so as to readily conform to the shape of the wearer; 3, a division into two zones, an upper and lower, so that between the two it may be secured tightly round the waist; for in no other manner can it be confined sufficiently close and secure round the body without such pressure over the chest and ribs as to materially affect the free action of the lungs, impede the muscular movement of the chest and arms, and thereby diminish the power of endurance of fatigue, which in rowing boats is a matter of vital importance; 4, strength, durability, and non-liability to injury. Life-preservers have been made of various other forms and materials, the object in view being to furnish a very buoyant article that can be readily and securely attached to the upper part of the person, or seized and held by those in the water. Hollow vessels of wood or tinned iron, made air-tight, and shaped so as to serve on board the vessel as seats, have been much used. In one form the seat is made double, and, opening on hinges, forms a rectangular float, in the centre of which is an aperture sufficient to admit the body of a man, his arms hanging over the sides. Bags of caoutchouc, so made as to be readily filled with air by blowing into them, and shaped for fitting round the neck or body, have also been largely employed for life-preservers; and they have been made into vests, shirts, and jackets, which can be distended with air, giving great buoyancy to the person wearing them.

One of the best life-preserving belts is that devised by Captain Ward, R. N., and largely used in all life-preserving services. The body of the belt is composed of light flax canvas, tarred to prevent mildewing; and the best of cork is firmly sewed on in slabs without covering. It sustains a dead weight of 28 lbs., a buoyancy of 16 lbs. only being necessary to support a living man in the water.

Merriman's life-preserving dress has achieved wide reputation through the extraordinary perform-

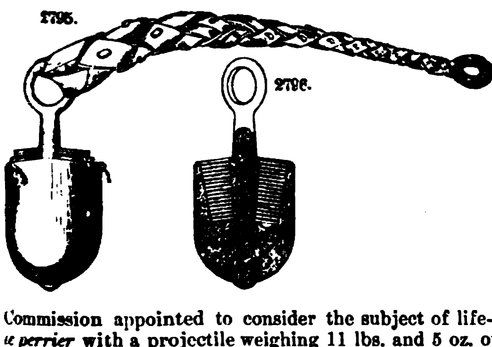
ances of Mr. Paul Boyton. Attired in this garment, he has successfully crossed the Straits of Gibraltar, a direct distance of about 30 miles, during a heavy sea, in 17 hours, has made a voyage of 600 miles on the river Tagus in Portugal and Spain, shooting several dangerous rapids and cataracts, and has traversed the Ohio and Mississippi rivers. The dress consists of an India-rubber head-dress, jacket, and pantaloons, the two latter connected by a joint around which is secured a belt to insure the junction being air-tight. It weighs about 14 lbs., and can be inflated in a minute and a half. The contained air serves to keep the body warm as well as to buoy it up. When in the water the wearer floats upon his back, having about one-third of his body above the surface, and propels himself by means of a paddle operated by the hands, or by the aid of a small sail attached to a rod fastened to one foot. A can for holding water and provisions and a small signal flag are provided with the suit.

Life-Buoys are floats carried on board ship and intended to be thrown to persons who have fallen overboard. The commonest form in which they are made is that of a ring about 30 in. in diameter, 6 in. wide, and 4 in. thick. This is made of painted canvas, and is filled with about 12 lbs. of cork. The life-buoys used in the U. S. Navy are constructed on Cook's plan. Each consists of two hollow metal cylinders, with rounded tops and bottoms, united by a horizontal bar through which passes a strong vertical metal tube. The lower portion of this tube is weighted so as to keep the buoy upright, and has a cross-piece on which the person clinging to it should place his feet, grasping the staff above the cylinders with his hands. On top of the staff is a small platform on which is placed a coil of port-fire. The buoy is usually suspended over the stern of the vessel by a slip-catch, which is easily loosened by pulling a handle. Another handle is arranged to spring a trigger, which frees a gun-lock hammer, which strikes a percussion-cap and so ignites the port-fire, which burns for some time after the buoy is in the water. These buoys are sometimes provided with a burning composition with which phosphide of calcium is combined. When this substance becomes wet it gives off a gas which ignites spontaneously, and the flame is not extinguished in the water.

LIFE-SAVING APPARATUS. The plan of establishing connection between a grounded vessel and the shore by means of a mortar-shot carrying a heavy line, was devised by Lieut. Bell in 1791; and he showed the practicability of the suggestion by an actual experiment in which a deep-sea line was carried to a distance of about 400 yards. He proposed that the gun should be carried on board ship, and intended that the plan should thus be put in practice, leaving the converse idea that mortars should be located ashore at various stations along the coast merely in the form of a suggestion. A description of Bell's invention appears in the "Transactions of the Society of Arts," xxv., 136. In 1810 Capt. G. W. Manby, R. N., made numerous practical applications of this last-mentioned idea of Bell. Official experiments conducted on Manby's system proved successful, and it was finally adopted. Manby first used a pear-shaped shot, and connected his rope to it by a line of plaited hide; but later a spherical 24-pounder shot or shell filled with lead, having an eye-bolt riveted into it, for the attachment of the hide rope, came to be employed. In 1857–'58 further experiments were made on the apparatus by Col. Boxer, superintendent of the Royal Laboratories, England, which resulted in the invention and adoption of the forms of Manby shot now in use at English life-saving stations. These forms are the 24-pdr. oblong or cylindrical shot shown in Figs. 2795 and 2796, and the 6-pdr. spherical. The first is a cylindro-conoidal projectile with a slightly rounded base, and measuring about 1½ calibre in length. It is provided with a wrought-iron bolt, to which is attached a plaited-hide thong. Four holes are drilled in the shot to receive fuses. The latter serve by the bright light which they give forth to indicate the path of the shot, and to guide the firing party in laying the piece. The projectile is placed in the gun with its base toward the muzzle, and upon the discharge of the piece carries out the line. The range varies from 400 yards downward, according to the strength and direction of the wind. A complete description of Manby's system, and a discussion as to the priority of his invention, appears in "Ammunition," Majendie, London, 1867.

In the French life-saving service two guns are used, known as *le perrier* and *l'espingole*. Their weights are respectively 183 and 44 lbs., and the weights of their projectiles 11 and 4.4 lbs. The extreme ranges are respectively 355.43 and 196.85 yards. In their report of Nov. 17, 1866, the French

2795. 2796.



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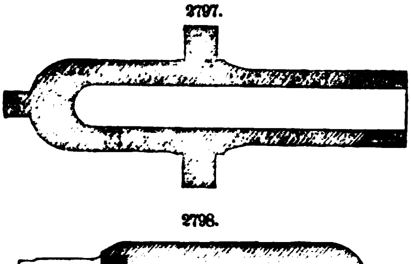

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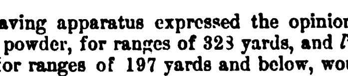

Commission appointed to consider the subject of life-saving apparatus expressed the opinion that *le perrier* with a projectile weighing 11 lbs. and 5 oz. of powder, for ranges of 323 yards, and *l'espingole*, with a projectile of 4.4 lbs. and 1¾ oz. of powder, for ranges of 197 yards and below, would be sufficient for all their needs. More recently in France M. Delvigne has invented a gun for projecting line-carrying arrows. These are either of wood or iron, the latter being used when the ranges are long and wind contrary. In 1872 a gun of this kind, weighing 44 lbs., gave a range of 328 yards with a wooden arrow weighing 17.68 lbs. and a shot-line .315 of an inch in diameter. The iron

arrows are about one-third longer than the gun, and about half the length of the arrow is in the gun when ready to fire. A description of the Delvigne gun appears in "Life-Boats, Projectiles, and other Means of Saving Life," by Capt. R. B. Forbes (1872).

THE U. S. ARMY EXPERIMENTS IN 1878.—An exceedingly valuable series of experiments on life-saving projectiles and guns has been made by Lieut. D. A. Lyle, U. S. Ordnance Corps, the full report of which appears in "Report of Chief of Ordnance U. S. A." for 1878. After various trials of rifled guns in comparison with smooth-bores, it was determined that the latter were best adapted for the purpose. Three guns are recommended, namely: 3-inch for 300 yards or less, with heavy lines; 2.5-inch for ranges of 400 yards and less, with service-braided lines; and 2-inch for 250 yards or less, with service line. These guns are chill-cast bronze, and the form is shown in Fig. 2797, which represents the 2.5-inch piece.

Projectiles.—These are modifications of Manby's shot, the calibre and weight being reduced. Fig. 2798 represents the projectile used in the gun illustrated in Fig. 2797. It is of cast iron, 15.7 in. long, and weighing 19 lbs. A wrought-iron shank or eyebolt is provided in the rear as shown.

Shot-Lines.—Linen lines are determined to be stronger than hemp, and to have more stretch per linear foot. Lieut. Lyle considers that preference should be given to unbleached linen thread for the manufacture of shot-lines. Great care should be taken that none but the best thread be put in such lines, and that in braiding a continuous line, when the spools are changed, they should not all be changed at the same moment, else a weak spot is the result. Bleaching of any kind is harmful. Hemp is too brittle, and becomes very harsh after a few shots.

Faking-Boxes are used to contain the shot-lines, and preserve them in readiness for firing at a moment's notice. The construction of a box is shown in Fig. 2799. It contains a number of hickory pins and a false bottom which slips over the pins. About these pins the rope is faked in a peculiar way, three men being required to do the work properly.

Extent of Range of Shot-Line.—A range of 400 yards is understood to be about the maximum range

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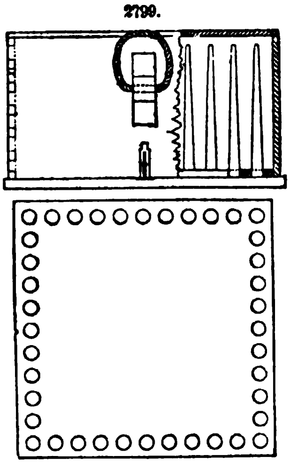

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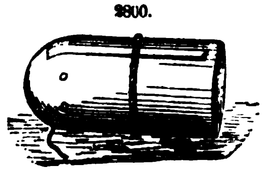
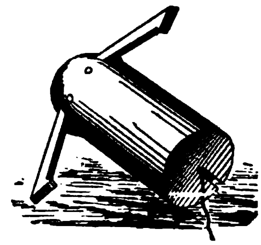


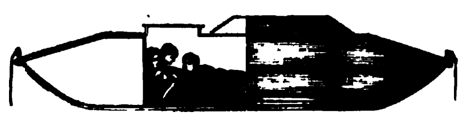
BEFORE FIRING.

2801.



AFTER FIRING.

2802.



necessary for the requirements of the service along our coasts, and it is not probable that a hawser and life-car can be used with success over even so great a distance.

Chandler's Anchor Shot.—Capt. Ralph Chandler, U. S. N., has devised a shot with hinged anchor-flukes projecting from its sides and folding back into slots, as shown in Figs. 2800 and 2801, so as not to interfere with the entrance of the shot into the gun. A chain or wire rope is attached to the rear of the shot, and carried to the front of the shot through another slot. In using the shot, it is inserted into the muzzle of the gun far enough to bring the ends of the arms inside. The chain or wire rope is attached to the rear of the shot, brought out under the slot, the strap taken off, and the shot pushed gently home. The springs under the arms, always flaring or pushing them outward, extend the arms as soon as the shot leaves the gun; and when the shot lands, the flukes enter and hold in the earth. Experiments were made on this device in July, 1878, with a 32-pdr. gun. The best results show that with 1 lb. 10 oz. of powder a shot weighing 78 lbs. was projected, carrying a line straight over a distance of 960 feet.

THE LIFE-CAR.—After communication with the wreck has been established by means of the line and shot as described, a larger rope is attached to the line and hauled over to the ship by the people on board. By means of this rope a still larger one—usually a 4-inch hawser—is got on board, and made fast as directed by those on shore by means of tallies attached to the line. The hawser is then set up taut by the people on shore, with tackles, sand-anchors, and crotches, and with the second or hauling line various appliances may be hauled back and forth until all hands are saved. The method of transporting persons from a wreck to the shore, used exclusively on the coasts of the United States, is by means of a covered metallic boat, known as the life-car, Fig. 2802, which is sufficiently large to contain four grown persons or eight small children. It is made of light galvanized iron, and when the hatchway is closed is nearly water-tight. The time usually occupied in arranging the lines and sending off the car, after firing the mortar, is about 30 minutes; and with the apparatus in proper

order the car can make the passage from the wreck to the shore, traversing in each trip a distance of 350 yards through a raging surf, within ten minutes. The life-car was introduced into the U. S. service in 1849, and in the following year was instrumental in saving 201 lives from the British emigrant ship Ayrshire, cast away on Squan Beach, N. J., during a fearful snow-storm. This mode of conveyance of passengers from wrecked vessels was the invention of Capt. Ottinger of the U. S. Revenue Marine. Its advantage over every other plan consists in landing women and children in perfect safety, and often without even getting wet. Fig. 2803 represents the life-car on the rope.

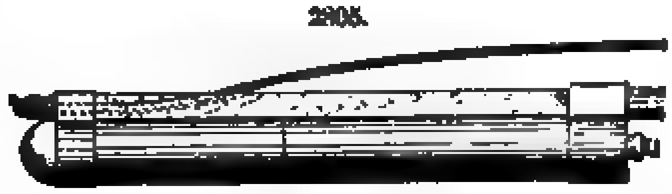
2803.

LIFE-SAVING ROCKETS may be used to carry lines to wrecked vessels when guns and shot of the type described are not employed. Boxer's rocket is represented in Figs. 2804 and 2805. It consists of two rocket bodies, one being fixed in prolongation of the other, to give great length of burning and flight, without any sudden violence, which might break the line which it carries, or irregularity from uneven burning. Thus it will be seen that instead of making one cavity in the rocket, two cavities are formed, with a portion of solid composition between them, so that when the solid composition is burnt through, the front cavity is ignited, thereby imparting to the rocket an additional impulse. The stick is fixed at the side of the rocket. The line is passed through a hollow at each end of the stick, as shown, and the end of the line is secured by a common overhand knot; two India-rubber washers and one brass washer are placed between the knot and the stick, to reduce the effect of the sudden jerk which is given to the line when the rocket is fired. Fig. 2806 shows the method of coiling the line carried by the rocket in its faking-box.

In 1870, 131 rockets fired successively at proof gave an average range of 373 yards, the maximum range being 470 and the minimum 330, the mean deviation being about 35 yards. As regards greatest range of rocket obtained under actual conditions, Mr. J. F. Spence, honorary secretary of the Tynemouth (England) Life Brigade, states as follows: "On the 8th of February, 1870, at 3:30 P. M., a large bark was stranded on the Spar Hawk, a spit of sand about half a mile east of the Black Midden Rocks, at the mouth of the Tyne; she would be about 350 or 360 yards, at least 350 yards by *measurement*, from the nearest point of the rocks on which we could stand to use the apparatus. The first shot fell far short of her, we suppose because it had not sufficient elevation, and the line was wet. The second rocket was laid with a few degrees more elevation, with a new rocket line quite dry and fresh, and flew right between her masts. The line is 250 fathoms in length. I think there might be 10 or 12 fathoms of the line left in hand. The wind was S. E. by S., force 10, blowing almost athwart the line."

2804.

2805.



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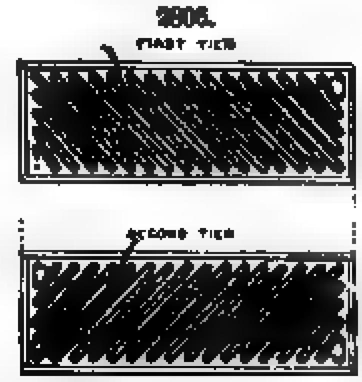


In relation to celerity of rescue of people from a wreck owing to this mode of communication, the same authority reports the most remarkable instance as that of "the schooner Light of the Harem, wrecked behind Tynemouth North Pier on the 8th of February, 1870. The rocket was fired at 30 minutes past 4 P. M., and the first man was landed in 14 minutes, the last man (there were five of them) in 24 minutes, from firing the rocket."

For a full discussion of this subject the reader is referred to Lieut. D. A. Lyle's paper already quoted in "Report of Chief of Ordnance U. S. A.," 1878; also to article "Service, United States Life Saving," in the "American Annual Cyclopædia" for 1878.

LIFTING JACKS. See JACKS.

LIFTS. See ELEVATORS.

LIGHT, ELECTRIC. See ELECTRIC LIGHT.

LIGHTER, ELECTRIC. See ELECTRIC GAS-LIGHTER.

LIGHTHOUSES, CONSTRUCTION OF. The materials used in the construction of lighthouses are wood, stone, brick, cast iron, and wrought iron. Stone, brick, and iron are the most important, and are used exclusively in all large lighthouses. The most noted lighthouses in the world are built of stone; and in northern climates, where the first cost is not the great consideration, stone should

be exclusively used. The form of all stone lighthouses approaches more or less the frustum of a cone or pyramid. They are sometimes built to include the keepers' apartments, but more usually they merely contain the staircase and cleaning and watch rooms, with a receptacle for the oil-butts. In all cases where large lighthouses are built of this material, the masonry should be of the best cut stone, with hydraulic-cement mortar. The first cost should never be so limited that this principle cannot be fully carried out. The same principle applies to brick lighthouses, which should be built of the best and hardest bricks, laid in hydraulic-cement mortar. The interior walls of all lighthouses should be as separate as possible from the outer walls, in order that there may be a free circulation of air between the walls. The dryness of the inner wall is insured by this arrangement, without which all large masses of masonry like large lighthouses must be constantly damp. The inner wall must of course be firmly tied to the outer shell by masonry or iron ties.

Cast-iron lighthouses were first erected by Mr. Alexander Gordon, an English civil engineer. Two were constructed in England, and were erected on the islands of Bermuda and Jamaica. From the fact that every part of the structure can be completed at the workshop, cast-iron lighthouses answer admirably for positions at points remote from large centres of manufacture, and are gradually coming into use. Several lighthouses of this kind have been erected at various places on the coasts of the United States. They require a lining of brick, the weight of which prevents oscillation or swaying, while its low conducting power of heat hinders the deposition of moisture on the well-room of the stairs, which would otherwise be occasioned by the difference of temperature between the inside and outside of the tower. To further this latter object, space is also left for a current of air to flow between the iron and the brick. Another kind of iron lighthouse is the wrought-iron pile lighthouse. The lower ends of the iron piles are fitted with large cast-iron screws where the foundation is soft, and the piles are screwed to a firm bearing; or where the foundation is rock, these ends are sharpened, and the piles are driven into the rock or hard ground by an ordinary pile-driver, until they come to a firm bearing upon cast-iron disks which bear upon shoulders forged on the piles. The number of piles depends upon the plan of the structure, which may be square, hexagonal, or octagonal. The foundation having been placed, the structure, which is of wood or boiler iron, firmly braced to the piles, and connected with them by iron castings, is easily built upon it. This kind of lighthouse was first built in England; the screw-pile was patented about 1836 by Mitchell, and is called Mitchell's screw-pile. It was introduced into the United States about 1845, and has since been used in the construction of many important lighthouses on the coast. Experience has shown that iron-pile lighthouses are not suitable for foundations in water in climates where much ice is formed. The ice, moving in large fields, bends and sometimes breaks the piles, and, by forming upon the piles themselves, makes the bulk of the structure so large that the effect of the waves upon it is very much increased. On this account it is not likely that iron-pile structures will be much used north of Chesapeake Bay; but on the southern coasts they have been found particularly adapted to the necessities of the service, and about 70 of this class of structures, resting upon screw-piles and iron disks, now exist in the United States. Their annual cost for repairs is very small, a yearly coat of paint being all that is needed to keep the exterior in good order. They are particularly suited for bays and sounds in the southern waters, where light-vessels have been in use until the present time. As these vessels become in need of repairs, they are withdrawn, and a screw-pile lighthouse is built upon the site, at a cost not much exceeding that of the repair of the vessel, and with an annual expense of maintenance less than one-half of that of the vessel.

Lighthouse towers are generally surmounted by parapet walls, which vary in height from 3 to 7 ft. according to the order of the light. Upon the parapet wall is placed the lantern in which the illuminating apparatus is contained. The lantern is a glazed framework made of brass or iron, and varies in dimensions from 6 ft. in diameter and 4 ft. in height to 12 ft. in diameter and 9 ft. in height. It is a regular polygon, and can be made of any number of sides, depending upon the various circumstances to be considered. It is surmounted by a dome constructed of copper or iron, which is generally lined with some other metal, leaving an air-space between the two metals, to prevent condensation of moisture. A ventilator is placed upon the top, from which the heated air escapes, and registers are inserted near the bottom of the lantern to enable the keeper to regulate the supply of fresh air at will. Upon the convenience and proper construction of the lantern the efficiency of the lighthouse in a great measure depends.

Lighthouse Masonry.—In Fig. 2807 are represented horizontal sections through the masonry of the Wolf Rock and five other lighthouses of the same general character, viz: Eddystone, Skerryvore, Inch Cape or Bell Rock, Minot's Ledge, and Spectacle Reef. These sections are taken uniformly at 10 ft. above high water, and are interesting as exhibiting the different methods of arranging the dovetail joints of the stones to prevent displacement by the sea. The impact against a lighthouse depends upon the relation subsisting between the height of the waves at the place and the height and configuration of the rock above and below low water, and perhaps also upon the configuration of the bottom of the sea at the place. Several examples corroborating this view are given in "The Design and Construction of Harbors," Stevenson, Edinburgh, 1874. The author points out that while the rock at Dhuheartach, from its height above the waves, forms a protection against the smaller class of waves, it operates as a dangerous conductor to the largest waves, enabling them to exert a powerful action at a much higher level than they would attain had the rock been lower. Hence the fact that the highest levels at which set stones were moved was at Carr Rock 3 ft. above high water, and at Dhuheartach 57 ft. above high water, may be accounted for by the different configurations of the rocks, without assuming that the waves are exceptionally high at Dhuheartach. The reader will find much useful information on the effects of storms on lighthouse masonry in the following works: "Account of the Skerryvore Lighthouse," Stevenson, Edinburgh, 1848; "Account of the Bell Rock Lighthouse," Stevenson, London, 1824; "Account of the Eddystone: A Historical Narrative of the Great and Tremendous Storm which happened November 26, 1703," London, 1769.

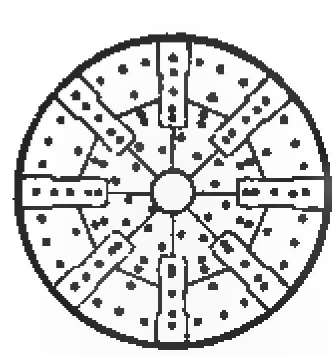
The Eddystone Lighthouse is celebrated on account of the difficulties attending its construction, and the fact that it is the type of all structures of the kind which have since been erected. It is located on the Eddystone rocks in the English Channel, near the port of Plymouth. The highest part of the rock, upon which the lighthouse is placed, is about 16 ft. out of water at low water of spring tides. The first lighthouse on this reef was erected by Winstanley in 1699, and was washed away during a

2607.

SKERRYVORE, SCOTLAND.

EDDYSTONE, ENGLAND.

MINOTS LEDGE, UNITED STATES.



WOLF ROCK, ENGLAND.

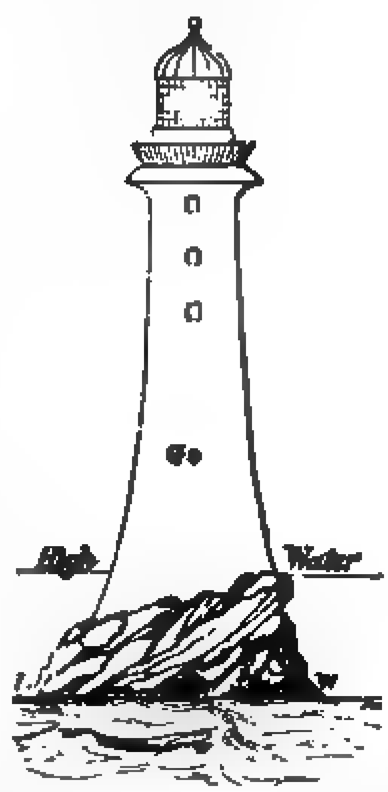
INCH CAPE or BELL ROCK, SCOTLAND.

SCALE:

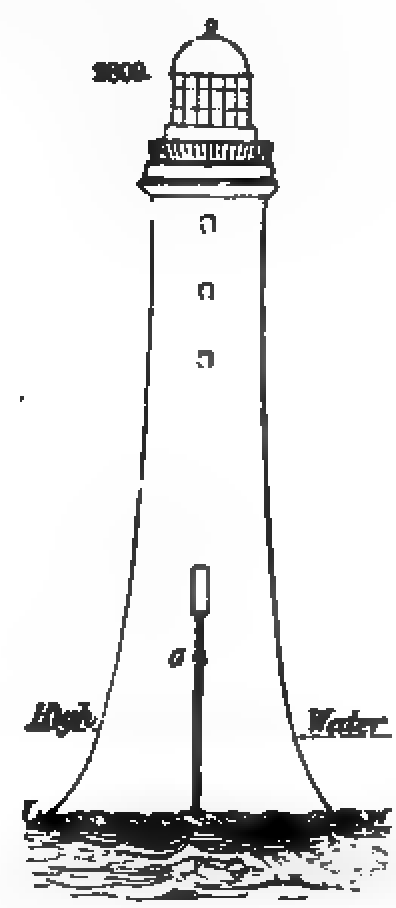
SPECTACLE REEF, UNITED STATES.

great storm in 1703. In 1709 Rudyerd completed another structure of wood and iron. This was destroyed by fire in 1755. In 1756 Smeaton undertook the construction of the present building, which is represented in Fig. 2608. He determined to use stone for the material, and the shape of the trunk of a large tree as his model. The stones of a course were joined by dovetailing, and the different courses were connected by stone dowels. The upper surface of the rock was cut in horizontal steps, so that every course of masonry rests upon a horizontal bed. The general form of Smeaton's structure is the frustum of a cone, or more strictly that of a solid of revolution formed by revolving a vertical plane bounded on one side by a concave curve around a vertical axis. The elevation, or a vertical section of the tower, indicates great strength. The diameter of the lowest partial course is 32 ft., and that of the first or lowest entire course is 26 ft. The diameter of the course under the coping is 15 ft., and the whole height of the masonry is 77 ft. The tower is surmounted by a parapet wall 6½ ft. high and 8½ ft. in internal diameter. The combinations devised for obtaining the greatest strength in this tower by dovetailing, cramping, dowelling, and by the use of hydraulic mortar, have never been surpassed. The experiments made by Smeaton on hydraulic cements in connection with the construction of this work were particularly valuable, and are still quoted. The erection of the lighthouse was, on account of its position, the difficulty of access to its site, and the fact that Smeaton had determined to build it of stone, attended with the greatest difficulties. The genius and energy of the engineer triumphed over all obstacles, and the work was finished in 1759. After standing for 120 years, a monument of the skill of its designer and builder, and an example to all engineers, owing to defects discovered in its foundation rock, its reconstruction was undertaken, and at the present time (1879) is in progress.

2608



2609.



Bell Rock Lighthouse.—The rock on which this structure is erected is situated in the German Ocean, 11 miles from the Scotch coast, on the north side of the Frith of Forth, and nearly opposite that of

Tay. The part of the rock on which the lighthouse is built is 12 ft. below high water of spring tides, the rise of these tides being 16 ft. The structure, shown in section in Fig. 2809, is of sandstone, the outer casing of the lowest 30 ft. being of granite. The difficulties of the erection of this lighthouse were nearly as great as those encountered by Smeaton in his work on the Eddystone, to which it is similar in form. The diameter of the bottom course is 42 ft., and that of the course just below the cornice 15 ft. The stonework is 102½ ft. high, in which height is included that of a parapet wall, octagonal in plan, which surmounts the tower. This wall is 6 ft. high, and its sides are 5½ ft. long; upon it the lantern is placed. The account of the erection of this lighthouse written by Mr. Stevenson and published in 1824 contains an accurate history of the Scottish lighthouses.

The Skerryvore Lighthouse, Fig. 2810, is located on the west coast of Scotland, on the Skerryvore rocks, about 11 miles S. W. of the island of Tyree and 50 miles from the mainland. The form chosen for the tower is a shaft surmounted by a belt and capital, upon which is the parapet wall. The shaft is a solid of revolution formed by revolving a rectangular hyperbola about its asymptote.

2810.

The diameter of the lowest course is 42 ft., that of the top course 16 ft., and the whole height is 138 ft. The tower for a height of 26 ft. is solid. Immediately above the solid part the walls are 9½ ft. thick, and they gradually diminish from this thickness to 2 ft. The material is granite, and the tower is surmounted by a bronze lantern in which is placed a Fresnel lens of the first order, showing a revolving light. The work was commenced in 1839, and the light was first shown in February, 1844. An account of the construction of the work has been published by Mr. Stevenson, which is valuable not only for the description of this particular work, but because it contains a dissertation on the Fresnel system of lighthouse illumination, and a succinct history of lighthouses. Figs. 2806, 2809, and 2810 show the comparative sizes and shapes of the Eddystone, Bell Rock, and Skerryvore lighthouses. The high and low waters of ordinary tides are indicated on the figures, and the letter *G* gives the position of the centre of gravity of each tower.

The Wolf Rock Lighthouse, Fig. 2811, is located off the Land's End, England, and is an excellent example of the most improved modern system of lighthouse building. The difficulties attending its

construction were exceedingly great, owing to the exposed position of its site. The rock of building was begun in 1862 and finished in 1869. The height of the tower is 116 ft. 4½ in. Its diameter at the base is 41 ft. 8 in., and near the top, at the springing of the curve of the cavetto under the lantern gallery, the diameter is 17 ft. For a height of 39 ft. 4½ in. from the base the work is solid, with the exception of a space forming a tank for fresh water. At the level of the entrance door the walls are 7 ft. 9½ in. thick, whence they gradually decrease throughout the whole height of the shaft to 2 ft. 3 in. at the thinnest part near the top. The shaft of the tower is a concave elliptic frustum, the generating curve of which has a major axis of 236 ft. and a minor axis of 40 ft. It contains 44,506 cubic ft. of granite, weighing 3,296½ tons; and its centre of gravity is 36 ft. 2½ in. above the base. The face-stone, as shown, is dovetailed both vertically and horizontally. A very full description of the construction of this lighthouse is given in Spon's "Dictionary of Engineering." Referring to the figure, *A* is the service-room; *B*, bed-room; *C*, living-room; *D*, oil-room; *E*, store-room; *F*, coal-room; *G*, entrance; and *H*, the water-tank.

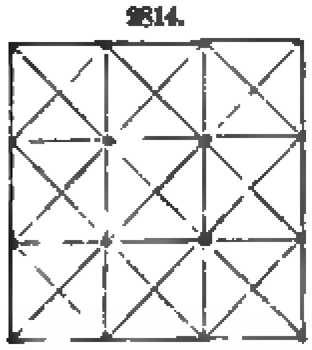
Minot's Ledge Lighthouse, a section of which is given in Fig. 2807, is situated on a ledge of rock about 8 miles E. S. E. of Boston. It is a granite tower in the shape of a frustum of a cone. The base is 30 ft. in diameter, and the whole height of the stonework is 88 ft. The lower 40 ft. are solid; the remainder of the tower is made up of keeper's apartments, store-rooms, and the parapet, which incloses the pedestal of the lens apparatus. The stones of the courses are dovetailed in the securest manner, and the courses are fastened to each other by galvanized wrought-iron dowels 3 in. in diameter. The lighthouse was begun in 1855, and was finished and lighted at the end of 1860, the work having been very difficult.

2813.

2812.

Coral Reef.

2814.



Sand Key, 1851.

Cast-Iron Lighthouses.—The first cast-iron lighthouse was erected at Point Morant, Jamaica, in 1842. The tower is formed of 9 tiers of plates 10 ft. high by three-quarters of an inch thick, united by bolts and flanges on the inside. The plates of each tier have a common radius. The tower is filled in with masonry and concrete to the height of 27 ft., and rests on a granite foundation. Its total height is 96 ft., the upper and lower diameters being respectively 18 ft. 6 in. and 11 ft. Fig. 2812 represents the cast-iron lighthouse erected for the Great Isaacs rocks near Bermuda, completed in 1856. The tower is 120 ft. high from the base to the plane on which the lantern rests, and 150 ft. to the top of the lantern. At the base the tower is 25 ft. in diameter, and at the top 14 ft. One of the great peculiarities of the construction is, that the 155 large cast-iron plates of which it is composed are not placed horizontally round the tower as heretofore in structures of a similar kind, but in what is technically called "break-joints"; i. e., the plates are dovetailed and wedged the one into the other, in such a manner as to form a perfect column equal in strength in all its parts.

Screw-Pile Lighthouses.—The screw-pile lighthouse at Sand Key, Florida reefs, is represented in Fig. 2813. This is supported on 16 piles, an auxiliary pile being placed in the centre to bear the

weight of the staircase. The foundation thus is formed of 17 screw-piles of 8 in. diameter, armed with a modified form of screw 2 ft. in diameter. The screws are bored 12 ft. into the reef, and the pile-heads are framed and braced together as shown in Fig. 2814. The superstructure of the frame-tower consists of six series of cast-iron tubular columns framed together, with wrought-iron ties at each joint, and braced diagonally on the faces of each tier. The keeper's house rests on a cast-iron floor, supported upon cast-iron girders and joists at the height of 20 ft. above the plane of the foundation top. The total height of the structure is 132 ft., or 120 ft. above the water level. Its foundation measures 50 ft. on each side of the square.

Fig. 2815 represents one of two similar lighthouses erected by the U. S. Government, at Trinity Shoals and Timbalier in the Gulf of Mexico. It is supported on 9 screw-piles, a central one surrounded by 8 others at distances of somewhat less than 15 ft. 4 in., each being 20 ft. distant from the central one, secured together at the ground by adjustable wrought-iron links, and above by diagonal braces, and by radial struts to the central pile. The summit of each pile is encased in a cast-iron socket for receiving the column and the radial and diagonal braces. The jointed columns which support the lantern have a similar provision for their diagonal braces, the arrangement of which will be understood from the figure. The different series of columns are jointed together by sleeves. The first series of columns above the foundation is 20 ft. long, the second 15 ft., the third and fourth 18 ft., the fifth, sixth, and seventh being respectively 15 ft. 6 in., 14 ft., and 12 ft. 6 in. The columns of the first series are of wrought iron, forged tapering; those above are of hollow cast iron, each series successively decreasing in diameter. The lantern is supported on a cylinder of boiler iron resting on a platform at the top of the columns. The height of this lighthouse is 131 ft. above the sea.

See "European Lighthouse Systems, 1873," Elliott, New York, 1875, and the annual reports of the U. S. Lighthouse Board. For lighthouse illumination, see LAMPS.

LIME-KILN. See KILN.

LINK-MOTION. See LOCOMOTIVE, DESCRIPTION OF PARTS OF THE.

LOCK, CANAL. See CANALS.

LOCK, GUN. See FIRE-ARMS.

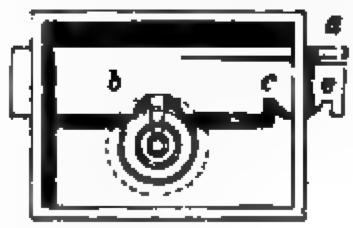
LOCKS. Fastenings for doors, boxes, etc., designed not to be opened except by an instrument called a key especially adapted to the lock, or by manipulating some secret arrangement of bolts and pins. There are an immense number of forms of locks, almost every manufacturer producing a variety of special patterns. The following is a summary of the principal types: A bolt-lock has its bolt so arranged that it can be driven or withdrawn only by the action of a key. A latch-lock can be opened by a knob on the inside, but requires the use of a key on the outside. Indoor and outdoor locks are so termed from their position on the respective sides of a door. Door-locks are also known as iron-rim, brass-case, or mortise locks, according to the quality and mode of fitting. The draw-back has a bolt capable of three positions, locked, latched, or open. The spring-stock is a wooden door-lock of inferior quality. The dead-lock or closet-lock has a single bolt. A two-bolt lock has a latch and a bolt. A three-bolt lock has an interior bolt, and cannot be operated from the outside. Knob and ring locks are so named from the forms of their handles. Right-hand and left-hand locks are arranged to suit doors opening to the right or left. A dormant lock is one having a bolt which will not close of itself. A spring-lock is one whose bolt is operated by a spring. A rim-lock is named from its shape. Ward-locks are so called from having wards corresponding to clefts in the key, into which they must enter before the key can be turned. They are known as one-ward, two-ward, etc., according to number; the round wards being sometimes called wheels, as one-wheel, two-wheel, etc. The shape of the ward sometimes gives the name, as L-ward, T-ward, and Z-ward. If the wards be cast solid instead of being made of a bent strip, the lock is termed solid-ward. A lock without wards is a plain lock. Straight locks have a plate screwed flat against the woodwork; cut locks are inserted into the woodwork, so as to lie flush with it. Mortise-locks are slipped into a mortise cut into the edge of the door. Tumbler-locks have one or more pivoted pieces called tumblers, provided with a lug or dog fitting a notch in the bolt, from which the dog must be released before the bolt can be thrown. Letter, puzzle, permutation, and combination locks have usually a series of notched rings, which must be turned until all the notches are in line in order to enter or withdraw the bolt. Wheel-locks are those in which one or more wheels form a part of the interior mechanism. There are also a large number of locks deriving their names from their adaptation to specific uses, while others bear fancy names given them by their inventors. A copious list of these is given in Knight's "Mechanical Dictionary."

The simplest form of lock is the *spring-lock*, the construction of which is shown in Fig. 2816. The bolt *b* passes through a rectangular hole in each end of the lock, and is held either out or in by two notches, *c*, *e*, which are pressed against the edge of the hole by the spring *a*. The face of the key is seen to lie in a semicircular notch in the lower edge of the bolt, which is by that means moved backward and forward. A number of circular partitions, called wards, whose edges are seen surrounding the shaft of the key, prevent any key which has not corresponding open spaces from being used. The ordinary key may have the form shown in Fig. 2817, but it is evident that it will answer the purpose of opening the lock as well if the parts are cut away, as in Fig. 2818; this is called a skeleton key, and is in common use among thieves in picking locks.

The common tumbler-lock, which has only been in use in Europe and this country during the last 100 years, is represented in its simplest form in Fig. 2819. The bolt *b b* is moved out and in by the key in the same manner as in the spring-lock, but it is held from moving by processes or projections in a tumbler, *a*, which are thrown by a spring into notches in the upper edge of the bolt. This tumbler has to be raised by the key before the bolt can be moved. Barron's lock, patented in 1778, is so contrived that the processes in the bolt have to be raised to a particular height in order that the bolt may be moved, because if raised higher they are thrown into opposite notches. The plan

is represented in Fig. 2820. This lock was considered secure for several years, when the ingenuity of burglars discovered a method of picking it. Mr. Barron subsequently added another tumbler, which had to be raised to correspond to another set of notches in the bolt, and thereby greatly increased the security of the lock. It is not certain that Barron applied more than two tumblers, but the principle of the many-tumblered lock is his. The form has been changed by putting a

2816.

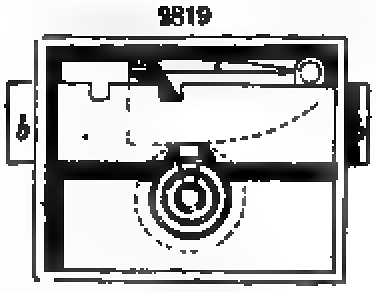


2821.

2817.

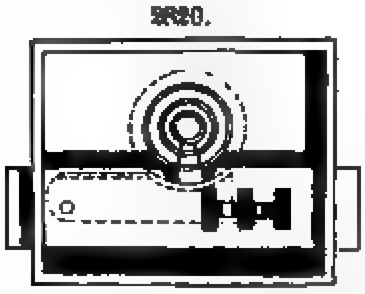
2818.

2819.



2822.

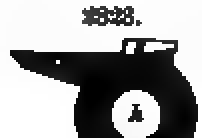
2820.



single pin called a stump in the bolt, which passes into slots in the tumblers, and these have to be raised to various heights in order to receive it. Chubb's lock has this form, as in Fig. 2821, where *b* is the bolt, *t* the tumblers (six in this cut), turning on the common pin *a*, *d* six springs to press down the six tumblers, and *n* the slots into which the stump *s* is drawn when the tumblers are raised to the proper height. The principle of Bramah's lock is similar, except that instead of tumblers turning upon a common pin, there are a number of independent slides having notches at different heights, but which are raised to a common height by a key having corresponding elevations on its face. It was supposed that a lock of the character of Bramah's could not be picked; and during the World's Fair in London in 1851 a challenge from the Messrs. Bramah, offering a reward of 200 guineas to any one who could pick a lock of theirs on exhibition, was accepted by Mr. Hobbs, an American. He succeeded after a trial of 51 hours, embraced in a period of 30 days.

Hobbs invented a lock called a "protector," which is represented in Fig. 2822. This is much like Chubb's lock, except that the stump *s*, instead of being riveted to the bolt, is riveted into a detached piece shown in Fig. 2823, which turns on a centre *h* when the stump *s* is pressed by the bolt. This

2823.



2824.

2827.

2828.

2825.

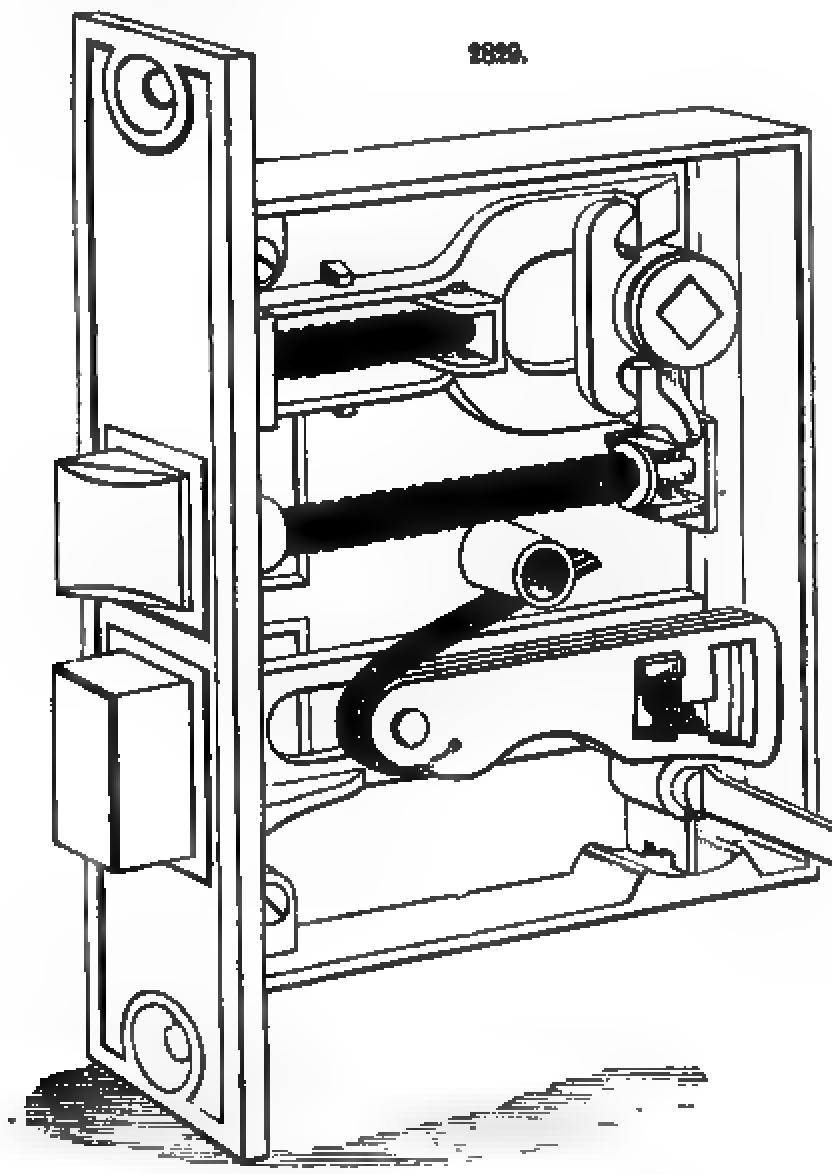
2826.

action brings the attached arm against the case of the lock, by which means the tumblers are relieved from pressure by the stump, so that their positions cannot be ascertained by the burglar. The key, Fig. 2824, turns on the pin *k*, and the tumblers rest on the piece *r*. This lock, after defying the ingenuity of English locksmiths, was at last opened by Mr. Linus Yale, jr., of Philadelphia, who has since invented the celebrated Yale lock, which is now used all over the world.

An improvement upon the form of the Hobbs and Chubb locks, in which the combination is not changeable, is the addition of a device by which the position of the slots and pins and the face of the key may be changed at pleasure. This was effected by Dr. Andrews of Perth Amboy, N. J., the principle of whose locks will be understood by inspecting the keys, Figs. 2825 and 2826, where the face of the key is changed by varying the positions of the separate pieces held in it. The lock is too complicated to admit of a description within the limits of this article. It was long extensively used by banks and large stores, and its success caused numerous competitors to appear, prominent among whom was Mr. Newell, the inventor of Day and Newell's "parautoptic lock."

The general plan of the Yale lock above mentioned is represented in section in the Yale night-latch, Figs. 2827 and 2828. An end view is shown in Fig. 2827, where a cylinder *C*, having a number of holes drilled along its whole length, as shown in Fig. 2828, may be turned when the key *K* raises the pins *a*, *b*, *c*, *d*, *e*, so that their faces are even with the surface of the cylinder. These pins are of corresponding different lengths in each lock, no two locks being alike. The flat key has bevel-edged notches in one of its edges, corresponding to the lengths of the pins. The parts of the lock shown here are called the "escutcheon," which not only comprises the cylinder, but the part above it, containing holes corresponding to those in the cylinder, and holding the same number of pins, 1, 2, 3, 4, 5, which, by means of spiral springs, are partly forced down into the holes in the cylinder when the key is withdrawn, thus fastening the lock. It will be seen that the faces of the two sets of pins must be in a line before the cylinder can be turned. Attached to the end of the cylinder, and not

2829.



2830.

2831.

shown in the cut, there is a cam by means of which the bolt of the lock is moved. The unlocking of the cylinder is performed by simply thrusting the key into it, and of the bolt by turning the cylinder with the key.

Flat keys are now largely used in standard door-locks. An example of a lock of this description is given in Fig. 2829. In this the key when inserted is carried by a small cylindrical hub, by which it is guided and supported during its rotation.

Safe and Burglar-proof Locks.—A large number of the permutation and combination locks used on safes are constructed on modifications of one general principle. This will be understood if we suppose the tumblers in a Chubb or Hobbs lock, instead of turning on a hinge at one end, to be converted into wheels and made to turn upon an axis, and, instead of having the slots brought to coincide by a key, adjusted by turning the wheels alternately one way and the other upon the axis on which they move independently. The wheels are placed near together, with washers between, and do not interfere with the motion of each other except when certain pins, which may at pleasure be moved to various positions, collide with one another; then one wheel will move its neighbor, and carry it around to any desired distance. Again turning it in the opposite direction, but through a smaller arc, another wheel may be turned until the slot in it is made to coincide with the first. A third and a fourth, and indeed any desired number of wheels (the number rarely ex-

ceeding four), may be adjusted with all their slots coinciding. The action is represented in Fig. 2830, where *a*, *b*, *c*, *d* are four wheels placed within the lock. Each wheel has a pin (shown only on *d*) which may be placed at pleasure upon any radius. A dial (Fig. 2831), turning by means of a knob upon an index-plate, is placed upon the outside of the safe. A shaft passes through the door and through the axis of a wheel to which it is fixed, and also through the axes of the wheels *a*, *b*, *c*, *d*, which, however, are free to turn. If now the fixed wheel has a pin upon its inner side which can be brought against the pin on the wheel *a*, it is evident that the slot may be made to correspond with any number upon the dial by adjusting the pin, and that by means of this dial the slot may

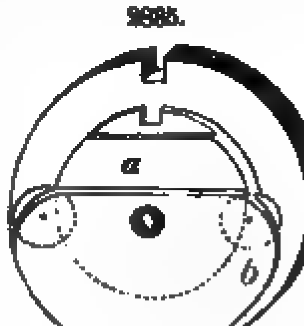
2832.

2833.

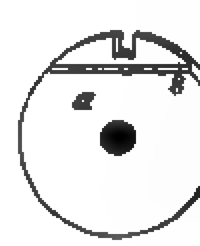
be placed in any determined position. If now the dial be turned around four times, the wheel *d* must be moved before or at the end of the revolutions by means of the pins in the wheels successively colliding. Suppose the wheel *d* to have its pin so placed that when the number 20 stands opposite the index on the index-plate, its slot will be in the position given in the cut. Now, on turning the dial in the opposite direction, the wheels will be unlocked, but in the course of one revolution the fixed wheel will again lock with the wheel *a*, and this again in the course of the second revolution will lock with the wheel *b*, and this in the third revolution with the wheel *c*. If this latter wheel has its pin so adjusted as to be opposite the number 40 when its slot is brought to coincide with that of the wheel *d*, this will be indicated when the number 40 is opposite the index. Reversing the motion of the dial, the wheel *b* may have its slot brought to coincide with that of *c* and *d* during the second revolution. Again reversing the motion of the dial, the wheel *a* will have its slot brought to coincide with that of all the others. When the slots in all the wheels coincide, the stump of the bolt may be thrown into the common slot, or a dog may fall into it, leaving the bolt free to move; or any other arrangement can be made which may be thought advantageous.

There are a number of excellent patents of combination-locks in this country, some possessing advantages of one kind and some of another. In the simple form just described, represented in Fig. 2832, where the stump of the bolts passes directly into the slot, there is danger of a burglar detecting its position by feeling while pressing it against the periphery of the wheel, and thus discovering the combination. This is prevented by various devices. One of those used upon Hall's lock is shown in Fig. 2833. It consists in notching the fixed wheel, which is somewhat larger than the others, so that the stump shall be pressed against it or into its slots instead of against the other wheels. The latter are also not circular, but polygonal, so that on turning them inequalities are felt which cannot be distinguished from slots. The device employed in the "Dexter lock," used on the Herring safe, is shown in Figs. 2834, 2835, and 2836. A false wheel *a*, Fig. 2834, smaller than the others, has a slot which receives an extra bar *c*, Fig. 2836, shorter and placed beneath the common bar for the other wheels; and also a shoulder *s*, which prevents the "fence" *a*, Fig. 2835, from descending when the slot is not uppermost. Over this small wheel is a cam *b*, Fig. 2835, which contains in each corner an octagonal roller, upon which the piece *d*, Fig. 2836, rests when the fence is raised. This piece *d* is constantly pressed by spiral springs, by which means all possibility of ascertaining when the bar *h* is brought opposite a slot in a wheel, or opposite any depression, is prevented. The locking in this arrangement is performed by raising the "fence" until the notch *e*, Fig. 2836, is brought to embrace the pin *g* attached to the bolt *f*. When the fence is depressed, the bolt may be moved backward or forward.

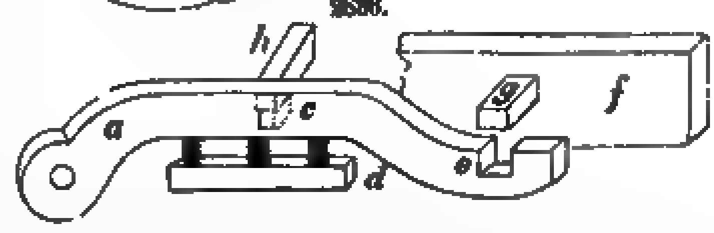
2835.



2834.



2836.



The Yale double-dial lock is represented in Fig. 2837. It consists of a heavy gun-metal case, measuring 7 by 9 inches, in which are two complete sets of permutating wheels or tumblers, each controlled on the outside by its respective dial and spindle. In the centre of the lock is a bolt which is common to and controlled by both sets of dials and their tumblers. The object of this mode of construction is to guard against the possibility of a "lock-out" arising from the accidental derangement of either of the two locks which are thus brought in combination. The bolt, being susceptible of control by either or both of the two dials, may be locked or unlocked by either of them independently of the other, and a lock-out is thus made impossible except in the most improbable event of both dials, and the mechanism controlled by them, being deranged simultaneously. A further pur-

pose of the invention is to guard against a lock-out by the forgetting of a combination. Each of the two dials being set by different persons on a different combination, the lock can be opened by either person in the event of the other's forgetting his combination or being absent. Another feature of this lock consists in the "outside spindles." It will be noticed that the spindles connected with the dials are placed entirely outside of the lock (their motion being transmitted to the tumblers by a train of gears), and it thus follows that, in the event of the displacement of the spindles by violence, the lock still remains intact, and guards the door. The spindles are made of hardened steel, to resist drilling, and are shouldered within the door so as to resist an attempt either to drive in or pull out.

The Yale Time-Lock is represented in Fig. 2838. The operation of this lock may be briefly explained as follows: Its function being to dog or obstruct the motion of the heavy bolt-work or gang-bolts now always used for directly securing the door of a safe to its jamb, the lock is provided in its right-hand upper corner with a sliding block of metal, which by the action of the clockwork alternately opens and closes an aperture in the end of the lock-case. A short tongue or stud rigidly connected to one of the gang-bolts is arranged to enter this aperture when the gang-bolts are retracted, and thus the closing of this aperture by the time-lock dogs or obstructs the unlocking of the gang-bolts until the time when by the action of the clockwork the aperture is uncovered, and the bolt-work left free to be retracted. In the lower part of the lock-case are two independent watch movements, each of them carrying on its main arbor a disk or dial, which rotates in the direction of the arrows. Each of these dials is provided on its periphery with 24 pins or stops, capable of a short endwise motion in the direction of the axis of the dial, which pins or stops, when pushed in, form on the back of the dial a projecting rim or cam, upon which travels the roller which carries one end of the yoke shown in the cut, and which in turn controls the counterbalance lever, the right hand of which actuates the sliding block which serves to cover the aperture in the case before referred to; the weight of the sliding block being slightly greater than that of the counterweight at the other end of the lever, its tendency is always to drop, and thereby uncover the aperture in the case. This tendency is resisted, first, by the yoke, and second, by the dials on which the yoke rests. If, however, the pins in the dials are pulled out, the support for the rollers carrying the yoke is removed, and the latter will drop, and the lock thereby open. Now each of the dials revolves once in 24 hours; and, the lock being adjusted to local time, the pins on each dial which represent the hours during which it is desired that the lock shall remain locked are pushed in, and the pins which represent the hours during which it is desired that the lock shall remain unlocked are pulled out, and the lock is then wound up and set running. This setting of the lock is of course presumed to occur during the daytime, when the lock is unlocked, and the right-hand end of the counterbalance lever is in its lower or depressed position (instead of lifted, as shown in the cut). Having properly set the lock, the user closes the door to which it is attached, throws the gang-bolts into the forward or locked position, and locks the combination or key-lock which usually also guards the door. Subsequently the action of the two time movements rotates the dials in the directions indicated by the arrows, and in due time this rotation causes the pins which are pushed in in each dial

2838.

to come in contact with the two rollers on the opposite ends of the yoke, and thereby lift the yoke and the counterbalance lever and sliding block, and thus close the lock. So long as the pins which are pushed in remain beneath the rollers, the lock remains closed; but the continued rotation of the dials causes these pins in time to pass away from beneath the rollers, and thus the yoke and the parts attached to it are permitted again to fall, and the lock to open. The yoke being pivoted to the counterbalance lever at its upper end, it is obvious that the concurrent action of both time movements is necessary to effect locking up; for if one remains in the unlocked position, the other will merely oscillate the yoke slightly on its pivot without affecting the counterbalance lever. When the lock is closed, however, unlocking can be effected by the movement of either one of the dials independently of the other, since the yoke will not support the lever and block if either of its supports be removed. It thus follows that the lock cannot *lock up* unless both movements are in good order and are running; but, on the other hand, either movement is competent to *unlock* the lock alone in the event of the others failing. On the back of each of the dials is a small cam or segment rotating on

2839.

2840.

the same centre as the dial, and traveling just outside of the pins. This segment is so geared to the dial that it makes one revolution to the latter's seven, and by properly setting this device in accord with the day of the week, it will then automatically interpose beneath the roller during the interval of one day in every seven, and thereby prevent the unlocking of the lock on the Sabbath. It will thus be seen that this lock is absolutely automatic; having once been properly set, it requires no further manipulation or attention beyond winding, and will continue so long as kept running to automatically lock up in the evening and unlock in the morning, at the hours for which it is set, and also automatically remain locked during every seventh day. The lock is also so constructed as to automatically unlock whenever its movements run down, irrespective of how the devices above described may be arranged: and it is thus guarded against all danger arising from carelessness in its use.

2841.

Marvin's Safe-Lock, represented in Fig. 2839, contains four tumblers and a cam-wheel or blind tumbler, which is equivalent to a fifth wheel. The tumblers are shown in position for unlocking in Fig. 2840. In Fig. 2839 the cam-wheel is shown at the bottom of the tumbler-box in the lock, with the dog just ready to drop into its slot, as the wheel is revolved by the dial on the outside. This operation, of course, throws the bolt back, and the unlocking is completed. When the lock is in the locked position, the dog is kept from dropping into the slot in the cam-wheel by the faces of the other tumblers; and they must first be brought into register, as shown in the cut, opposite the arm of the dog, before it will drop, and this can be done only from the outside by working the combination. The tumblers are held fast in the tumbler-box by a key-lock on one side and a spring-catch on the other, in order to prevent their being disturbed by any jar or shock in opening or shutting the safe-door, or from any external violence. The spindle operating the lock enters the safe at one side, and is connected with the tumbler-spindle by a train of gears.

Sargent and Greenleaf's Tumbler is represented in Fig. 2841. *A* is the tumbler-wheel, which rotates around the interior wheel *B*. The rim of wheel *B* is toothed, and engaging therein are the toothed faces of arms *C*, which are held in contact by light springs. While the parts are thus engaged the tumbler cannot be turned to alter the combination. To effect the latter object, a key is inserted at *D*, by turning which the arms are moved out of contact with the wheel *B*, and the tumbler *A* can then be turned as desired.

LOCOMOTIVE. See LOCOMOTIVE, DESCRIPTION OF PARTS OF THE; LOCOMOTIVE, INTERNAL DISTURBING FORCES OF THE; LOCOMOTIVE, PROPORTIONS OF THE; LOCOMOTIVE—TRACTION, ADHESION, AND RESISTANCES; LOCOMOTIVES, CLASSIFICATION AND FORMS OF; LOCOMOTIVES, INSPECTION AND DRIVING OF.

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See also the following references to periodical literature: "Locomotives at the Paris Exhibition, 1878," *Railroad Gazette*, x. and xi.; "Locomotives at the Philadelphia Exhibition, 1876," *Railroad Gazette*, viii.; "Locomotives at the Vienna Exhibition," *Engineering*, xvi. and xvii.; "Fireless Locomotive," *Railroad Gazette*, ix., 383; "Forney's Locomotive," *Railroad Gazette*, ii., 145 and 156, and x., 11; "Fairlie's Locomotive," *Railroad Gazette*, ii., 445; "Locomotives of the Pennsylvania Railroad," *Engineering*, xxiv.; "Mallet's Compound Locomotive," *Railroad Gazette*, ix., 560; "Experiments with Resistances of Railroad Trains," made by Vuillemin, Dieudonné, and Guebhard, *Mémoires et Comptes-rendus des Ingénieurs Civils*, 1868, p. 701; "Die Ermittelung des Widerstandes, welchen Eisenbahnfurwerke in Curven erfahren auf experimentalirem Wege," Von Weber, *Organ für Eisenbahnwesen*, 1863, p. 1; "Versuche über die Zugwiderstände in Curven auf der Altona-Kieler Bahn," *Organ für Eisenbahnwesen*, 1870, p. 135; "Indicator-Versuche an Locomotiven," Bauschinger, *Civil-Ingenieur*, xiii., 479; "Experiments with Train Resistances," Dixon, *Engineer*, 1862, p. 21; "Experiments with Train Resistances at Different Speeds," Gooch, *Proceedings of the Institution of Civil Engineers*, vii., 292; "Resistances of Trains," Harding, *Proceedings of the Institution of Civil Engineers*, v., 405; "Resistance of the Air," *Mechanic's Magazine*, xxx., 244, 265, 297, 300, and 362; "Verderber's Locomotive Boilers," *Railroad Gazette*, 1879, p. 110. T. F. K.

LOCOMOTIVE, DESCRIPTION OF PARTS OF THE. The term locomotive is generally used to designate a wheeled vehicle actuated by steam or other power, which power is generated and applied by apparatus contained in or upon the vehicle itself. The term is more specifically used with reference to the steam motor employed for the traction of cars on railroads. It has also been extended to the self-moving vehicles which are intended to run on common highways. (See *Traction Engines* under ENGINES, PORTABLE AND SEMI-PORTABLE.) Locomotives were devised originally for this last-mentioned purpose, the railroad being an invention of subsequent date. The first successful application of steam as a motive power for vehicles was made in Europe in 1768, by Cugnot of Paris; in this country in 1772, by Oliver Evans of Philadelphia. In 1813 Blackett first determined by experiment that the adhesion of the locomotive—the friction between the wheels and rails with flat surfaces (see ADHESION)—constitutes sufficient resistance to prevent skidding of the wheels, and thus enable a locomotive to advance and to draw a train without the use of chains applied to stationary posts or of racked or cogged rails. This latter means of affording augmented resistance to the wheels is, however, necessarily used on mountain railways which are built on steep grades, and the locomotives adapted to these rails constitute a separate class. In 1814 George Stephenson constructed a locomotive with two cylinders, which was a considerable advance over the primitive locomotive having but one cylinder. Gillingham and Winans, of Baltimore, were the first to effect a variable expansion, by using separate eccentrics for each point of cut-off. Great difficulty was experienced in causing locomotive boilers to generate steam in sufficient quantity to meet the requirements of the high-pressure engines. In 1827 Marc Seguin, a French engineer, overcame this obstacle by devising fire-tube boilers, and thus increasing the heating surface necessary for rapid evaporation. The foregoing are the chief improvements; others have multiplied rapidly, until at the present time the locomotive seems to have reached a point beyond which it is difficult to foresee progress except in the way of refinements and minor modifications.

There are many styles and types of locomotives, varying in their dimensions, proportions, and general design. The last-mentioned difference exists chiefly in the number and kind of wheels used, and their relative positions to each other, and with regard to the whole locomotive. The locomotives of different nations also exhibit specific differences. Every locomotive, however, possesses the same essential features, the chief parts in all instances performing the same functions, and being indispensable. A locomotive may be said to consist of three distinctive parts or organs, namely: the steam-generator or boiler, the steam-engine, and the running gear. Each of these portions will be treated separately, and the type which is known as the "American locomotive" is chosen as an example, for the purpose of explanation of the general construction of a locomotive. Figs. 2842, 2843, 2844, 2845, and 2846 represent, respectively, a side elevation, the longitudinal section, the plan, the back-end view, and two half cross-sections, of the eight-wheeled American locomotive, as built by the Grant Locomotive Works.

PARTS OF THE LOCOMOTIVE.—The following are the parts of the locomotive designated by the letters of reference in the figures already referred to: *A*, *A*, cylinders; *B*, main driving-axle: *C*, *C*, main connecting-rods; *D*, *D*, main crank-pins; *E*, *E*, truck-wheels; *F*, back driving-axle; *G*, fire-box; *H*, *H*, *H*, frames; *I*, *I*, frame-clamps; *J*, *J*, eccentrics; *K*, *K*, rockers; *L*, *L*, links; *M*, lifting-shaft; *N*, *N*, lifting-arms; *O O*, reverse-lever: *P P*, cylinder part of boiler; *Q*, smoke-box; *R R*, smoke-stack or chimney; *S*, pilot or cow-catcher; *T*, head-light; *U*, bell; *V*, sand-box; *W*, whistle; *X*,

THE AMERICAN LOCOMOTIVE.

dome; *Y Y*, cab or house; *Z*, back or trailing-wheel crank-pin; *A'*, pump air-chamber; *B'*, *B'*, main driving-wheels; *C' C' C'*, supply-pipe; *D'*, front platform; *E'*, bumper timber; *F'*, *F'*, back driving-wheels; *G'*, coupling-pin; *H'*, friction-plate; *I'*, check-valve; *K' K'*, foot-board; *L'*, lazy-cock; *M'*, mud-drum; *N'*, *N'*, driving-springs; *P'*, pump; *R'*, drop-plate of grate; *S'*, steam-gauge; *T' T'*, feed-pipe; *U'*, *U'*, forward eccentric-rods; *V'*, *V'*, backward eccentric-rods; *X'*, lifting-shaft spring; *Y'*, *Y'*, dampers; *Z'*, pushing-bar; *a*, *a'*, tubes; *b b*, grate; *c*, fire-box door; *d d*, ash-pan; *e k*, reverse-rod; *f*, *f*, exhaust-nozzles or blast-pipes; *g*, safety-valve lever; *h*, *h*, cross-heads; *i i*, running-board; *j*, throttle-stem; *k M*, reverse arm; *l*, throttle-pipe; *m m*, dry-pipe; *n*, T-pipe; *o o*, steam-pipe; *p*, petticoat-pipe; *q*, smoke-box door; *r*, piston; *s*, spark-deflector or cone; *t t*, wire-netting in stake; *u u u*, boiler-lagging; *v v*, truck-spring; *w w*, sector or quadrant; *x*, blow-off cock; *y*, truck centre-pin; *z*, throttle-lever; *a'*, *a'*, tubes; *b' b'*, truck-frame; *c' c'*, bed-plate; *d'*, boiler-brace; *e' e'*, sand-pipe; *f' f'*, equalizing-lever for driving-wheels; *g'*, *g'*, guide-bars or rods; *h' h'*, receptacle for sparks; *i' i'*, bell-rope; *j' j'*, brace-yoke; *k'*, valve-stem; *l' l'*, truck-equalizing lever; *m' m' m'*, hand-rail; *n'*, blow-off cock in mud-drum; *o'*, spring-balance; *p'*, pump-plunger; *q'*, *q'*, foot-steps; *r'*, brace to smoke-box and frame; *s'*, *s'*, steam-chests; *t'*, *t'*, *t'*, crown-bars; *u'*, head-light lamp; *v'*, main valve; *w'*, blow-off cock handle; *x'*, bell-crank for throttle-valve; *y'*, piston-rod; *z'*, draw-bar; *A"*, *A"*, house-brackets; *B"*, *B"*, hand-holds for getting on and off the locomotive; *C"*, stand for tallow-can; *D"*, feed-cock quadrant; *D" E"*, rod for operating feed-cock; *J"*, *J"*, doors in front of the cab; *K"*, *K"*, windows in front of the cab; *a"*, *a"*, heater-cocks; *a" a"*, heater-pipe; *b"*, blower-cock; *c"*, *c"*, cylinder oil-cups; *d"*, handle for opening valves in sand-box; *e" e"*, handle for opening pet-cocks; *f"*, handle for opening cylinder-cocks; *g"*, whistle-lever; *h"*, rod connecting whistle-lever with the handle; *i"*, whistle-handle;

f'', handle for left-hand feed-cock; k'', glass water-gauge; l'', water-gauge cocks; m'' m'', lever for shaking the grate-bars; n'', bell-crank for opening front ash-pan damper; o'', rod connecting safety-valve lever with spring-balance; p'', pipe for carrying off water from gauge-cocks; q'', spring-balance lever for safety-valve; r'', handle for opening blow-off cocks; s'', drip-pipe for gauge-cocks; t'', link-hanger; u'', cross-brace; v'', v'', rocker-arms; x'', x'', check-chains; z'', spring-hangers.

The Locomotive Boiler, represented in a longitudinal section and a cross-section through the fire-box in Figs. 2847 and 2848, consists of a cylindrical portion $P P$, which forms the boiler proper, containing the fire-tubes $a\,a'$ and smoke-box Q; and a rectangular compartment U, in which are the fire-box and the fire-grate m. The material of which the boiler is made is iron or steel in sheets, copper being sometimes used for the inside fire-box shell, and brass for the tubes. In this country, however, steel and iron are almost exclusively employed for these purposes. The sheets are connected by rivets placed in single rows circumferentially, and double rows longitudinally—the latter being also used where the cylindrical portion joins with that of the fire-box. The joints are made tight by calking. In the front part of the boiler is the smoke-box Q, usually of a cylindrical shape, forming a prolongation of the boiler, to which it is riveted. Sometimes the smoke-box has a square bottom, to suit the shape of the steam-cylinder castings, on which it usually rests. The outer end of the smoke-box is strengthened by a wrought-iron ring riveted to it, to which the smoke-box front q is bolted. A hinged circular door in the latter admits of the cleaning of the smoke-box and the fire-tubes. A circular plate $a'\,a'$, riveted to the boiler-shell, separates the smoke-box from the boiler, and holds the fire-tubes, which communicate between the fire-box and the smoke-box. This is called the smoke-box tube-sheet or flue-head.

The cylindrical portion of the boiler consists of two or more sheets, usually lapped on each other, but sometimes

2845.

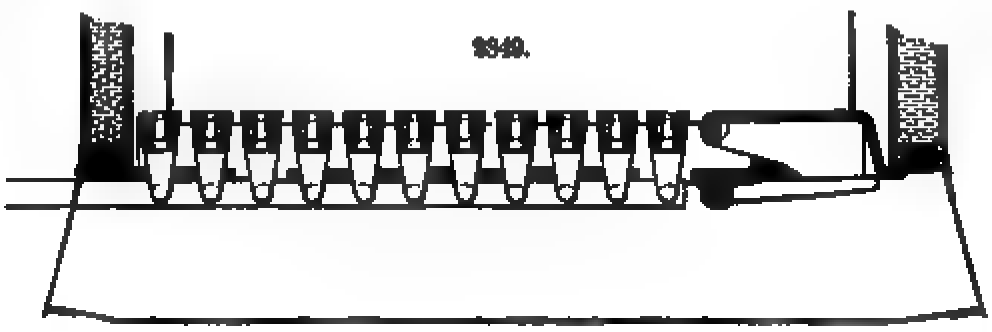
2846.

brought in contact edgewise, and riveted to an outside ring or welt, forming thus a joint with a smooth inside surface, which is less liable to corrosion. At the bottom of the cylindrical portion of the boiler is the mud-drum or pocket *M*, which serves to keep the boiler clean from the mud which collects in it, and can be discharged by taking off its cover. A blow-off cock is usually screwed into the mud-drum cover for emptying the boiler. The fire-box portion of the boiler consists of the outside and the inside shell. The outside shell is composed of two side-sheets, *B A* and *E F* (Fig. 2848), a back or door sheet, *B A* (Fig. 2847), a front sheet, also called waist, *E F*—all four of a flat form—and a top or crown sheet, *C D*, which is either bent in a circular shape or is also flat. The corners are rounded, and the joints made by lapping the sheets one on another. The outside fire-box crown-sheet is usually raised above the cylindrical portion of the boiler, giving thus a larger steam-space; and the outside width of the fire-box is at the top, usually more than the diameter of the boiler, narrowing toward the bottom (see Fig. 2848), where it is limited by the locomotive frame. The fire-box outside shell unites with the cylindrical part by a short portion of the boiler, of conical shape, which is made of two sheets, one at the top, the other at the bottom. In this country a steam-dome *X* is always placed at the crown-sheet. In Europe it is usually located in the neighborhood of the smoke-box, the opinion prevailing that the steam is there drier, and that an advantage is gained by the shortening of the steam-pipes leading to the cylinders, which are placed on the outside of the boiler. The inside fire-box shell, or the fire-box proper, consists of two side sheets commonly bent into form corresponding to the outside form, a door-sheet, a waist or front sheet, a crown-sheet, *g g*, which is either of flat or semicircular shape—the latter being now favorably regarded by many engineers—and a tube-sheet, *a a*, to which the fire-tubes are fastened. At the bottom, the two fire-box shells are joined, and the water-space between them closed, by a wrought-iron bar, which is riveted to them and makes a tight joint. The fire-door channel *C* is of sheet iron, and is riveted to the two back sheets. The doors are of cast iron, hinged, and provided with a latch, and often have air-holes with a slide to close or to open them. The fire-tubes are made tight at the fire-box tube-sheet, usually by expanding them at that place into a tapered shape to fill the hole, lapping the ends over the sheet, and, at the inside edge of the sheet, expanding them into a ridge. A short copper ferrule on the outside of the tubes is used for tightening these joints. At the smoke-box end the tubes are simply expanded and lapped over. The cylindrical parts of the boiler, by their form, are strong in themselves, and do not require any bracing; but the flat portions, at the fire-box, are strengthened by stay-bolts, *n n*, which join the outer and inside shells by being screwed into the sheets, and being headed like rivets at their ends. These stay-bolts are either of wrought iron or copper, and are often perforated with holes, to be easily discovered when broken by the leakage of water through them, which would then take place. The flat portion of the outer-shell side-sheets, which stand above the inside crown-sheet, are braced by rods, uniting them together; and the corresponding portion of the back sheet is braced by long rods to the upper part of the smoke-box tube-sheet, and to the outside crown-sheet. The back sheet is also braced by flat bars, called angle-braces, to the side-sheets at their extremities, in cases where the extreme rows of the stay-bolts stand far from their edges. The bracing of the inside crown-sheet is more difficult, and can be

effected in different ways. Usually, if the inside crown-sheet is flat and the outer one round, crown-bars, *f f*, are placed at the top of the first, which are riveted to it in rows, thus giving it great strength. The strength of the crown-bars is often increased by bracing them to the outside crown-sheet and to the steam-dome by rods *d d* and braces *e e*. Should both crown-sheets have the same form, either flat or round, they are simply braced to each other by bolts, having heads on the top and nuts on the inside of the fire-box—copper washers being placed under the head and the nut, to keep the joints tight. When the circular form of the crown-sheets renders them sufficiently strong to withstand the pressure, they are not braced at all. At each corner of the bottom of the fire-box hand-holes are made, to admit of cleaning the boiler from mud and scale. Sometimes the hand-holes are numerous and placed in various parts of the boiler, especially if the water which is used gives much scale. Cast-iron plates, one from the inside, the other from the outside, held tight by a bolt and a nut, close the hand-holes. A blow-off cock is usually screwed to the bottom of the back sheet (*X*, Figs. 2843 and 2846).

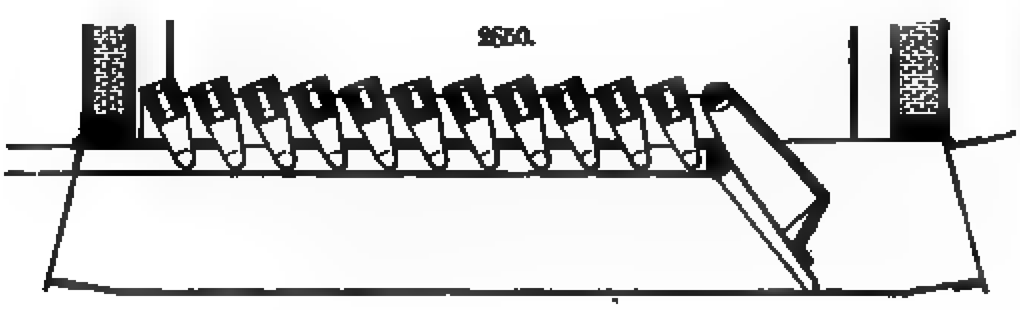
Various devices have been tried to increase the steaming capacity of locomotive boilers. These principally consist in introducing in the fire-box brick arches, midfeathers, or water-pockets. The

2849.



2848.

2850.



water-pockets are either suspended from the crown-sheets, raised from the bottom, or joined to the water-spaces of two sides of the fire-box. The object of such arrangements is to increase the direct heating surface, and to create combustion-chambers, where the flame can be thoroughly mingled with air before entering the tubes. Devices of this sort can be looked upon as experimental only; they have never met with general application.

The boiler on the outside is protected from losses of heat by a lagging, usually consisting of wood and very thin sheet iron, fastened by means of brass or iron straps.

The Grate is placed at the bottom of the fire-box. Its form varies according to the properties of the fuel that is burned on it. For wood or coal, which does not require shaking to make the ashes fall through, rectangular wrought- or cast-iron bars, of considerable depth and small width (usually several of them being joined in one section), are laid on two or three cross-pieces fastened to the fire-box bottom ring. These sections of grate-bars can be arranged to swing on their axes (see Figs. 2849, 2850, and 2851), in which case they are provided with cranks projecting downward, which connect with a rod that receives a reciprocating movement from a vertical lever by a bell-crank. By this means the fireman is enabled to shake down the fuel. Such grates are called "shaking-grates." Similar to this is the "rocking-grate," the difference being that, instead of several bars being united

in a section, there is but one bar having horizontal fingers, standing at right angles to it at both sides. The free space between these fingers is occupied by the fingers of the neighboring bar. The bars swing on their longitudinal axes. Another form of grate, which is always used for anthracite coal, is called a "water-grate." This consists of water-tubes screwed in the front and back sheets of the inside fire-box in a zigzag line, as shown in section in Fig. 2852. Between these tubes are placed three or more solid round iron bars (shown in black section), which are pushed from the outside through rings in the back water-space of the fire-box. By removing these, the ashes can be thrown down through the free space thus made between the tubes. A drop-plate, placed at the front end of the fire-box (see Figs. 2849, 2850, and 2851), and serving to throw the fire out, is often used with grates. It swings on journals which are not in its centre-line, and is held horizontally by two arms of a shaft which is manipulated by means of a bell-crank and rods from the locomotive platform. If the support is withdrawn, one side of the plate overbalances, and it falls down, leaving an open space in the grate.

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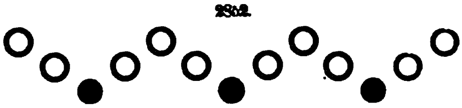

Under the grate, attached to the boiler by means of angle-iron, is the *ash-pan d' d'*, Figs. 2847 and 2848, of thin sheet-iron, often provided with a slide beneath for throwing the ashes down on the ground. It has dampers in front and behind, which are hinged and connected by bell-cranks to vertical rods, by means of which the fireman is able to shut or to open them.

The Smoke-Stack.—On the top of the smoke-box is placed the chimney or smoke-stack, *R R*, Fig. 2847, through which the smoke and gases, produced by combustion of the fuel on the grate in the fire-box and passed to the smoke box through the tubes, escape. The steam exhausted from the cylinders also escapes by it. There are many forms of smoke-stacks. A short pipe, slightly tapered in straight or curved lines, having the smallest diameter at the top, of sheet or cast iron, forms a base for the stack. It is bolted or riveted on the smoke-box by means of flanges. To it is attached the smoke-pipe, usually of sheet iron, which is left open, or covered with a wire netting to arrest the sparks; or, as is the case on American locomotives burning wood or soft coal, it ends with a special top, consisting of two cones, placed one above the other, and meeting at their largest portions. At their junction a plate perforated with many small holes, or a wire netting, *t t*, is placed across. Under this netting a cast-iron cone or spark-deflector, *S*, is suspended with its point down, the object of this being to deflect the heavier sparks, which are thrown back or broken and extinguished. If wood is used as the fuel, the smoke-pipe is surrounded by another pipe, concentric with it, and standing on the same base. The top is then attached to the outside pipe, and the space between the two pipes serves as a receptacle, where the sparks collect and can be discharged by an opening made at the bottom. For anthracite coal the pipe is made straight without the conical top, and the spark-arrester is provided only with a simple netting. In Europe smoke-stacks are almost always made with straight tops. Occasionally the pipe is made slightly tapered, the larger diameter being at the top. This form has an advantage, as it admits of the use of a wider exhaust-nozzle, thus diminishing the back pressure in the cylinders. A smoke-stack cover, consisting of a disk which swings on a vertical shaft attached on the outside of the stack, and moved by the fireman from his platform, is used on European locomotives to regulate the draught. In the smoke-box, under the chimney and concentric with it, is attached the so-called "petticoat-pipe," *N*, Fig. 2847. This is sometimes made in two telescoping parts, so that it can be lengthened or shortened. It is a conduit for the exhausted steam from the nozzles to the chimney. It is used only on American engines, and is said to produce an even distribution of draught through the different rows of tubes.

Boiler Attachments.—A *steam-gauge*, *S'*, Figs. 2843 and 2846, the construction of which is the same as of the gauges used on the high-pressure stationary boilers (see Boilers, Steam), is placed on the crown-sheet facing the engine-driver. A glass water-gauge, *k''*, and three or more gauge-cocks, *l''*, Fig. 2846, are placed on the fire-box back sheet, directly under the eye of the driver, and serve to show the height of water in the boiler.

Safety-Valves.—Two or more safety-valves are usually provided to prevent the steam-pressure in the boiler from exceeding a certain limit, 120 to about 145 lbs., and thus to guard against the danger of explosion. Two kinds of these valves are in ordinary use on American locomotives. One of these is the common safety-valve, which is loaded by a spring-balance, *o'*, Fig. 2846, consisting of a spiral spring, usually attached to a handle *q''* on the steam-gauge stand, and acting on the longer end of a lever *g*, Fig. 2843. At the other end of the lever is the fulcrum, fixed on the steam-dome cover; the lever presses down the valve, which is placed at a short distance from the fulcrum. The engine-driver can release the valve from pressure, or load it, by means of the handle *q''*. The other valve used is known as Richardson's valve. It has its spring directly over it, and is so constructed that the escaping steam strikes a cavity surrounding the outside rim of the valve, and is deflected downward, where it meets another cavity in the valve-seat. By this means the pressure of steam on the valve is increased immediately after the valve is opened, and thus the increase of the pressure of the spring, resulting from its compression, is counteracted. Safety-valves are sometimes loaded with weights suspended at the end of levers, but springs are more commonly used. To effect a constant pressure on the valve loaded by a spring, connected to the end of a lever, Mr. Meggenhoffen has invented an arrangement which consists of a bell-crank, one arm of which is connected with the spring and the other with the lever. When the valve is closed, the arm of the bell-crank which is acted upon by the lever is in a vertical position (position of the axis of the spring); and when the valve rises, this arm changes its position from vertical toward horizontal. Just the opposite position is that of the other arm of the bell-crank, which is acted upon by the spring. To produce an equilibrium, the momenta of both forces acting on the two arms of the bell-crank must be equal; that is, the force

acting at the end of the lever, produced by the steam-pressure on the valve multiplied by the horizontal distance from the fulcrum of the bell-crank, must be equal to the force of the spring multiplied by the horizontal distance from the same fulcrum. When the valve rises from its seat the force of the spring increases, but at the same time its horizontal distance from the fulcrum diminishes, while the distance of the other applied force from its fulcrum increases. It is evident that by giving the proper proportions to the arms of the bell-crank, a constant equilibrium can be produced. The Ramsbottom safety-valve is another device which of late years has been introduced on European locomotives. This consists essentially of two valves loaded with two springs by a direct pressure; the lift of the valves being very small, the force of the springs is nearly constant. On American locomotives, as already stated, there are only two safety-valves, both placed on the steam-dome cover; in Europe three or more valves are used, which are usually attached to the steam-dome cover and at some other part of the boiler.

A steam-whistle, *W*, Figs. 2842, 2843, and 2846, is placed on the dome-cover, and is operated by a lever g'', with handle i'' placed convenient to the hand of the engine-driver. This serves for signaling between the driver and brakemen, etc. Two *heater-cocks*, a'', a'', Fig. 2846, attached to the crown-sheet, allow of the passage of steam for heating water in the tender with the superfluous steam from the boiler, when the throttle is shut. A *blower-cock*, b'', Fig. 2846, is attached to the crown-sheet, and serves to increase the draught in the chimney by admitting a jet of steam directly into the chimney, as practised in Europe, or under the petticoat-pipe, as in this country.

Pumps.—One or two force-pumps serve to supply the boiler with water. These are of the single-acting plunger type, as represented in Fig. 2853. The plunger $B\,B$ is moved either by an eccentric fixed on the axle, or by a rod attached to the cross-head (see p', Fig. 2844) in the pump-barrel $A\,A$, being kept air-tight by means of a stuffing-box C. The pump-barrel is cast in one with a perpendicular cylinder, which communicates at the bottom with the suction-pipe D, leading from the water-tank, and at the top with the discharge-pipe $E\,E$, which communicates with the water-space of the boiler. The communication between the pump-barrel and the two pipes is governed by two valves G and F, called respectively discharge and suction valves. These are of cylindrical form, fitted water-tight to the seats $g\,g$. Their movement is guided and limited by "stops" or "cages" $k\,k$, shown more clearly in Fig. 2854. The action is as follows: When the plunger is drawn out of the barrel, a vacuum is there created. The valve G will thus be closed by the pressure of water in the discharge-pipe E, while the valve F will be lifted from its seat by the pressure of the water in the tank. Consequently the barrel will be filled with the supply-water. When the plunger makes its return stroke, it presses on the water in the barrel, which then closes the valve F and opens the valve G, entering through the latter to the discharge-pipe. To prevent the damaging effect of the sudden arrest of the motion of the water, when reciprocating, air-chambers J and $K\,K$ are attached respectively above and below the discharge and suction valves. When the water reaches the height $d\,c$ of the discharge-pipe in the chamber J, it begins to compress the air inclosed therein, which thus forms an elastic cushion. The same effect is produced in the air-space between the cylinder L and $K\,K$ when the water reaches the height $a\,b$. The discharge-pipe E communicates with the boiler through a second discharge-valve H, called "check-valve," of the same construction as the other, which closes against the steam-pressure from the boiler. Its object is to prevent the hot water from entering the pipe, and also to prevent its leaking out from the boiler in case the pump should be damaged. In the air-chamber J, at m, is attached a cock, called the "pet-cock," which can be opened by means of a rod with the handle placed in the cab. The discharge of water through this shows whether the pump is working. The pumps are attached to the frames as shown in Figs. 2843, 2844, and 2846.

The water-supply of the pumps is regulated by so-called "feed" or "lazy cocks," which are placed under the footboard (see L', Figs. 2842, 2843, and 2846). These are coupled to the pipes and connect them to the tank; they are operated by rods and handles. The handle for the right-hand side lazy-cock is provided with a "quadrant" D', Fig. 2846, on which the amount of opening is shown by a finger.

Injectors (see INJECTORS) are widely used for feeding locomotive boilers, either replacing the pumps or being used in addition to them.

The Throttle-Valve.—The admission of steam from the boiler to the cylinders is regulated by the

throttle-valve *k*, Figs. 2847 and 2848, usually placed in the steam-dome, and sometimes in the smoke-box. In this country the form of valve almost exclusively used is known as the poppet-valve. This is made double to counterbalance the steam-pressure, and to hold the valve on its seat. A cast-iron pipe *l*, called throttle-pipe, is fastened in a vertical position in the steam-dome, and has horizontal branches at the bottom and the top. The top branch ends with a short vertical cylinder *h*, open at both ends. These ends are closed by two circular disks, connected together, and constituting the valve. The upper disk opens the cylinder by being raised to the outside, and the lower by being moved inside of the cylinder. It is evident that when the valve is closed the steam presses at the upper side of the top disk and at the lower side of the bottom disk, and if the two disks have the same area both pressures are balanced, and the valve can be opened without presenting any resistance; but as it is important that the valve should close the throttle tightly, the upper disk is made slightly larger than the lower one. It being difficult to make two such disks thus connected to fit perfectly on their seats, an arrangement has been adopted in Europe in which the upper disk only is used as a valve, while for the lower one is substituted a piston packed with rings. The object of the lower piston is only to balance the pressure, and not to admit the steam. The valve is fitted on a vertical rod, which connects by a bell-crank with a horizontal stem *j*, provided with a stuffing-box at the back sheet of the fire-box, or in some cases at the steam-dome. The stem is pivoted to the throttle-lever (see *s*, Figs. 2843 and 2846), which, by means of a latch fitting into notches of a segment, can be fastened in any position. Sometimes a more complicated arrangement is used—geared wheels, or a combination of levers—to enable the engine-driver to regulate very minutely the opening of the throttle.

The most common form of throttle-valve used in Europe is a slide-valve with several ports, to diminish its travel; such valves are mostly vertical. They move between guides, and have a spring pressing them to the seat. The object of this is to allow a little play between the valve and its seat, which prevents breaking of the throttle when the engine, on being reversed while in motion, pumps air toward the boiler. To counteract the pressure of steam, which opposes the opening of such valve, a second and smaller valve, sliding on the back of the first, is often attached to it; this small valve, being moved at first, opens two small ports, through which steam is admitted on the other side of the large valve, balancing thus the pressure. Further movement of the small valve will take with it the large valve. It being necessary to lubricate such valves, an oil-cup is placed on the dome-cover, from which oil is carried to them by a small pipe.

2855.

Instead of a throttle-lever, as used in America, a crank attached to a horizontal shaft, which imparts its movement to the valve-stem by means of an arm, is often employed in Europe.

The lower horizontal branch of the throttle-pipe communicates by a so-called "dry pipe," *m m*, Fig. 2847, with a casting *n*, Figs. 2847 and 2855, attached to the smoke-box tube-sheet, and named "T-pipe." The two branches of this communicate with the steam-pipes *o o* leading to the cylinder castings.

The steam-pipes in America are always placed in the smoke-box. In Europe they are often placed on the outside, when they branch off directly from the throttle, and are carried out through the shell of the steam-dome, which is near the cylinders; or the throttle, being somewhat differently constructed from the manner above described, is attached to the top of the boiler, near the smoke-box, and takes steam through a dry pipe from a steam-dome, placed at the fire-box end of the boiler. Sometimes two steam-domes are used, the throttle communicating with both. Steam-pipes are usually connected together with ball-joints, which admit of an easy adjustment, notwithstanding the irregularities caused by inaccurate construction or the influences of temperature.

The Exhaust-Nozzles.—Steam, having made its way through the throttle and steam pipes into the cylinder, escapes, after performing its duty, through the exhaust-nozzles (*f f*, Fig. 2855) into the smoke-stack. No better use could be made of it, this being the only means of creating draught. By this means a small locomotive boiler is able to generate steam in sufficient quantity, and more rapidly than any other kind of boiler. The smaller the openings of the nozzles, the greater the rapidity with which the steam escapes through them, and the better is the draught; but there is a limit to the diminution of this opening, as upon it also depends the back pressure on the piston in the cylinders. To enable the engine-driver to regulate the exhaust, a variable opening to the nozzle is sometimes given. An exhaust-nozzle consists of a conically-shaped cast-iron pipe, which communicates with the exhaust-pipes *e e* of both cylinders, and either joins them in one opening, when it is called "single nozzle," or only brings them close together without joining them. When there are two openings the term "double nozzle" is used. The double nozzle is not employed in Europe.

The nozzle is there always carried up to the base of the smoke-stack, while in America it ends where the petticoat-pipe begins. The variable exhaust-nozzle is constructed in various ways; but usually it consists of two conical frusta, the upper one being the smaller, and arranged so that it can slide up and down in the larger one. When moved to its highest point, it forms with the other a single cone, and the opening of the nozzle is then most contracted.

THE LOCOMOTIVE STEAM-ENGINE. — *The Cylinders.* — The locomotive steam-engine consists of two cylinders, *A A*, Figs. 2842 to 2846, acting on the same shaft or axle by means of cranks placed at right angles to each other. The cylinders are of the same construction as for ordinary stationary engines. (See ENGINES, STEAM, STATIONARY RECIPROCATING.) Their axes are parallel with that of the boiler, and they are placed usually at the smoke-box end—exceptionally toward the centre of the locomotive. Regarding the position of the wheels, the cylinders are placed either on the inside or the outside of them; the latter design is more general, and in this country is almost exclusively used. In the first case they are located under the boiler, with steam-chests usually in the centre, to which steam- and exhaust-pipes are directly attached. In the second case, either a separate casting, containing intermediate pipes for steam and exhaust, joins the cylinders, and forms a so-called "saddle" or seat for the smoke-box, or one-half of such saddle is cast to each cylinder, and the two are bolted together. The latter arrangement, which is the most common in America, is represented in Fig. 2356, which shows a cross-section through the exhaust-pipe of the one and through the steam-pipe of the other cylinder. The letters of reference designate the following parts: At *D D* are the two castings, which are bolted together at *j*, and to the locomotive frames *F F*, by bolts *m k*; the smoke-box sheet rests at *E E* on the saddle. At *J J* are the steam-chests, separate castings, which are closed with covers *K K*, and secured together with them to the cylinders by bolts *p p*. At *V V* are the valves (one shown in section, the other in end view), which slide on the valve-seats *h g*. At *G G* are the cylinder steam-pipes, through which the steam flowing from the boiler steam-pipes *O O* enters the steam-chests. At *H H* are the cylinder exhaust-pipes, through which the steam, leaving the cylinders through the cavity under the valves, enters the exhaust-nozzles *C C*. At *a a* are two rings which can be fitted on the exhaust-nozzles to diminish their openings, or to enlarge them when removed. At *b b* are the set-screws to fasten the rings *a a* on the nozzles. At *C C* are the cylinder-cocks, which can be opened or closed from the cab, and are connected to a lever and rods operated by a handle *f''*, Fig. 2846. These serve to discharge the condensed water from the cylinders. At *w w w* are the cylinder laggings or jackets, usually of wood with a metallic sheet on the outside, which protects the cylinders from the loss of heat by radiation.

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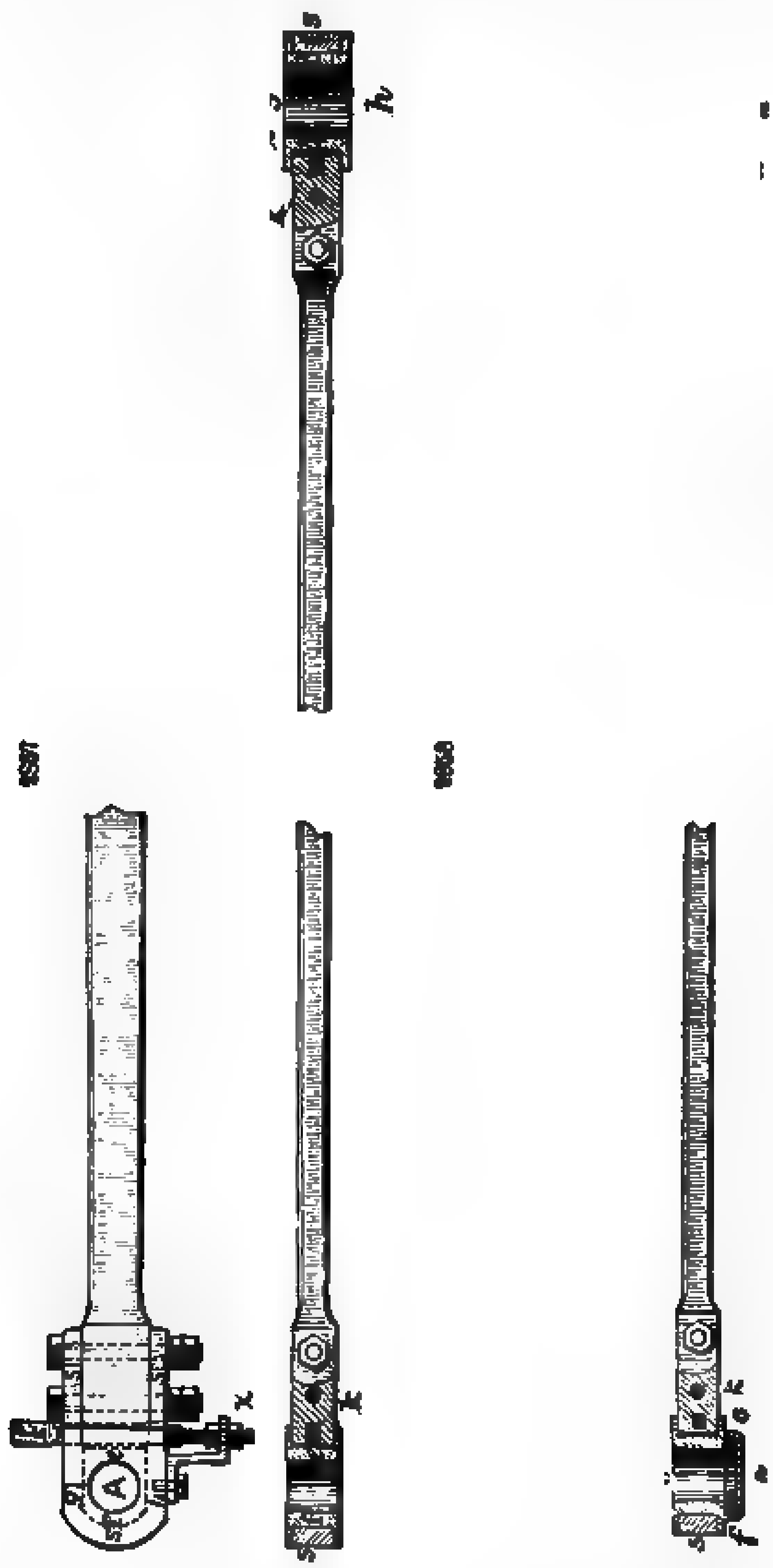
The steam-chests on outside cylinders are usually placed on the top, and rarely at the bottom or sides. The distribution of steam in the cylinders is effected by means of the ordinary three-ported slide-valve, and only in Europe, occasionally, a separate cut-off valve is used. Locomotive engines, being of variable expansion, where the changeable cut-off is effected by the change in the travel of

the valve, require unusually long steam-ports to diminish the losses in efficiency of steam from wire-drawing. The steam-ports are thus made in length nearly equal to the diameter of the cylinder. To prevent the wire-drawing of steam on account of small opening of the ports, the Allen valve is largely employed in Europe. It is the common slide-valve with an inside channel around its exhaust-port, which begins as near the edge of the valve as practicable. When the valve with its steam-edge has opened one of the steam-ports, the channel is also uncovered at the other end to the steam of the chest, its edge having passed the edge of the valve-seat, and the steam is thus admitted into the cylinder-port from the outside and through the channel. The slide-valve is attached to a wrought-iron "yoke," which is made solid with the stem; the latter is connected to the valve-rod by means of a key or a right- and left-hand screw, or by being pivoted. The steam-chest is either cast solid with the cylinder, or is a separate piece. It has one or two stuffing-boxes, the latter arrangement being used when the steam-chest is not on the top of the cylinders, in which case the valve-stem projects at both ends of the chest.



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To lubricate the valve-seat and the cylinder, a self-feeding oil-cup is placed on the steam-chest cover, or the oil is carried through pipes connecting the chests with the oil-cups c'', c'', Fig. 2846, placed on the boiler, in the cab. On locomotives provided with the Le Chatelier apparatus (see BRAKES), water is sometimes admitted into the steam-chest for lubrication. The cylinders are closed with cast-iron covers bolted to their flanges. The pistons are packed with Babbitt brass or cast-iron rings, and are attached to the piston-rod with a nut or key. At the other end of the piston-rod, which crosses the cylinder-cover through a steam-tight stuffing box, is keyed on the cross-head. (See h, Figs. 2842 to 2846.)

Locomotive cross-heads are of several forms, and are made of cast or wrought iron or steel. A common American form of locomotive cross-head is one with two slides, placed respectively on each side, moving between two pairs of guide-bars. The wrist-pin, which joins the connecting-rod with the cross-head, is cast solid with it. Sometimes the cross-head is made to slide on one bar only, the wrist-pin being then placed below the bar, as also the connection with the piston-rod. In Europe, and on most of the American freight locomotives, the cross-head is made to slide between one pair of guide bars, such construction being preferable as it takes less width. Cross-heads are often provided with brass gibs, or plates placed on slides, with an adjustment to take up the wear They are lubricated from cups attached to the guide-bars.

The guide-bars (see g' g', Figs. 2844 and 2846) are attached to the cylinder-cover at the one end, and at the other end to a "yoke-brace," j', which brace is fastened to the locomotive frame, and in this country also to the boiler. Guide-bars are always square-shaped, of steel or wrought iron, and serve to guide the cross-head in its straight-line motion. If no provision is made to take up the wear on the cross-head slides, this is accomplished by bringing the guides nearer together, by filing off the blocks on which the guides bear. The motion of the cross-head is transmitted by a main connecting-rod to the crank-pin of the main driving-wheel (see the general drawings, Figs. 2842 to 2846), which, if there are more than one pair of driving-wheels, is coupled by so-called "coupling" or "parallel rods" with the crank-pins of the other driving-wheels.

Connecting-Rods.—The usual form of locomotive connecting-rods is shown in Figs. 2857 and 2858, representing respectively the main and the parallel rod. The main connecting-rod is coupled at A

with the cross-head, the pin of which is grasped by the brasses *f e*, secured to the rod with a strap *s s* and bolts; a key *k*, provided with a screw-spindle and two nuts at *x*, serves to take up the wear of the brass ring, which is for that purpose made in halves. The complete end of a connecting-rod is called "stub-end." The other stub-ends of the connecting-rods are, as seen in the engraving, constructed similarly to the one described, the only difference being that the parallel rod has at one end (sometimes at both) two keys, one on each side of the crank-pin. The object of this is to keep the distance between the centres always the same, and equal to the distance between the axles. To diminish friction and prevent heating, each stub-end is provided with an oil-cup which lubricates the bearing. A parallel rod which couples three or more axles is made in two or more parts, which are jointed together by pivots; such arrangement is necessary, as the axles, and consequently the crank-pins, following the inequalities of the track, are often out of a straight line. There are also other forms of stub-ends for locomotive connecting-rods besides those illustrated, namely, ends made solid with the rod, without a separate strap. The brasses are then held in position only by the keys. The use of a simple steel or brass bush in the parallel-rod stub-ends is popular in Europe.

The Link-Motion.—The distribution of steam on the locomotive engine is effected by the movement of a common slide-valve, in the same manner as on stationary engines; but as the locomotive has to run in both directions, the valve must receive its motion from two eccentrics—one for the forward, the other for the backward movement. The change of action from one eccentric to another used to be accomplished at first by hand, by disconnecting the valve-rod from one of the eccentric-rods and connecting it with the other. Soon after, the ends of both eccentric-rods were permanently connected by a slotted bar (see Figs. 2859, 2860, 2861), in which a block, pivoted with the end of the valve-rod, moves up and down. The slotted bar, now commonly called a "link"—hence "link-motion" is so arranged that it can be raised or lowered, so as to place the block in front of one of the two eccentric-rods, thus reversing the engine rapidly, even while the latter is in motion. The intermediate points of the link, between the eccentric-rods, also travel; but the nearer they are to the centre, the shorter is their movement. This property of the link-motion has been advantageously utilized to work the engine with variable expansion. (See ENGINES, STEAM, STATIONARY RECIPROCATING.)

There are various kinds of link-motions now used on locomotives, some receiving the movement from eccentrics, others from cross-heads and eccentrics, or from cross-heads and connecting-rods; but the largest application, and in America that which is almost exclusively used, is the Stephenson link-motion. Fig. 2859 shows the arrangement of this device on an American locomotive. On the main driving-axle *S* are fastened two eccentrics, *J* and *K*, by means of screws or keys, with cast-iron

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eccentric-straps on them, to which the eccentric-rods *C* and *D* are bolted; the eccentric-rods are jointed with the link by means of pins *e* and *f*, and knuckle-joints; the centres of these pins can also be placed on the centre-line of the link, on the outside of the extreme ends *a b* of the link. *B* is the sliding block, which imparts its movement to the lower rocker-arm *h c*, by means of a pin *c*. A pin *i* connects the upper rocker-arm *h i* with the valve-rod *k*; *h* is the rocking shaft, which transmits the movement from one rocker-arm to the other, and which is attached to the locomotive frame by a rocker-box, as shown. The introduction of a rocking shaft in the link-motion is peculiar to American practice—the cylinders with steam-chests being outside and the eccentrics inside of the wheels. The link is suspended at its centre on a hanger, *g l*, which is pivoted at *l* with the link-saddle *L N*, bolted to the link. The hanger at *g* is pivoted with an arm *E* of the lifting or reversing shaft *A*, which shaft has another arm parallel with it, and on it a second link for the other engine of the locomotive is suspended. A third arm *F*, on the shaft *A*, is pivoted to a rod *G*, called reach-rod, which at its other end connects to the reversing lever placed in the cab. The point of suspension of the link, *l*, swings in an arc of a circle whose radius is *g l* and the centre *g*. This centre *g* is stationary for a certain point of cut-off; but when the latter has to be changed, or the engine reversed, the reversing shaft is moved by means of the reversing lever and the rod *G*. The centre *g*

describes a circle with the radius $A\,g$ from the centre A. As the links and their attachments are of considerable weight, and besides the friction of the valve opposes any change of position, it is necessary to counterbalance this whole resistance. This is accomplished by a spring placed in a casing H, and fastened to a cross-brace n, which, acting on a rod m attached to a short arm o of the shaft A, assists the engine-driver in raising the link. Countorweights are used for this purpose in Europe.

The Stephenson link does not give a perfectly correct distribution of steam; the lead varies for different points of cut-off, the period of admission and the beginning of exhaust are not alike for both ends of the cylinder, and the forward motion varies from the backward. All these irregularities—which could be almost nullified if the space and other considerations in regard to the whole locomotive would admit of giving the proper proportions to the different parts of the link-motion—are practically so far overcome as to be disregarded. Usually the forward gear of the link-motion is corrected, but this, being accomplished at the expense of the backward gear, can be advantageous only for locomotives running in one direction, and not for double-enders.

The correctness of the distribution of steam by Stephenson's link-motion depends upon conditions which, as much as the circumstances will permit, ought to be fulfilled, namely: 1. The link should be curved in an arc of a circle whose radius is equal to the length of the eccentric-rod. 2. The eccentric rods ought to be long; the longer they are in proportion to the eccentricity, the more symmetrical will the travel of the valve be on both sides of the centre of motion. 3. The link ought to be short. Each of its points describes a curve in a vertical plane, whose ordinates grow larger the farther the considered point is from the centre of the link; and as the horizontal motion only is transmitted to the valve, vertical oscillation will cause irregularities. 4. The link-hanger ought to be long. The longer it is, the nearer will be the arc in which the link swings to a straight line, and thus the less its vertical oscillation. If the link is suspended in its centre, the curves that are described by points equidistant on both sides from the centre are not alike, and hence results the variation between the forward and backward gear. Should the link's centre move in a straight line (this has been accomplished by Von Landsee, but with some complication in construction), the movement of both halves of the link would be alike. If the link is suspended at its lower end, its lower half will have less vertical oscillation, and the upper half more. Such a mode of suspension would be advantageous for an American locomotive, the lower half of the link being its forward gear. 5. The centre from which the link-hanger swings changes its position as the link is lowered or raised, and also causes irregularities. To reduce them to the smallest amount, the arm of the lifting shaft should be made as long as the eccentric-rod, and the centre of the lifting shaft should be placed at the height corresponding to the central position of the centre on which the link-hanger swings.

All these conditions can never be fulfilled in practice, and the variations in the lead and the period of admission can be somewhat regulated in an artificial way, but for one gear only. This is accomplished by giving different lead to the two eccentrics—which difference will be smaller the longer the eccentric-rods are, and the shorter the link—and by suspending the link not exactly on its centre-line, but at a certain distance from it, giving what is called "the offset."

Regarding the connection between the link and eccentrics, there are two cases to be distinguished: If the crank is in its forward centre (toward the link), and the eccentric-rods do not cross each other (that is, when the upper eccentric connects with the upper end of the link, and *vice versa*), the link is said to be with "open rods;" while if the rods, in this position of the gear, cross each other, the link is said to be with "crossed rods." The difference of action in the two cases shows itself in the lead, which increases when the link is shifted from the full to the mid gears.

The following are other forms of link-motion which are applied to locomotives in Europe: The Gooch link-motion consists of a stationary link, in which the block is raised or lowered to effect the different expansions or the reversing of motion. The block is jointed to the valve-rod, the other end

2860.

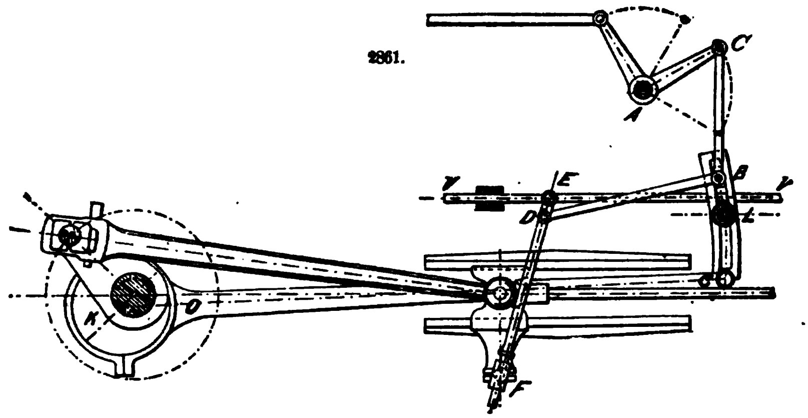
of which is pivoted with the valve-stem. The curvature of the link faces the valve-rod, and its radius is the length of the rod. Hence it follows that the block can be shifted without producing any change in the position of the valve, admitting thus a constant lead.

The Allen link-motion is the combination of the two foregoing. It has hitherto been a difficult job in the workshops to finish a curved link, especially one of a large radius, and the Allen link-motion has been devised to overcome this difficulty. It is represented in Fig. 2860, and consists of two eccentrics acting on a straight link L; a valve-rod R, jointed at its end a to the sliding block, which is pivoted to the valve-stem S at b; a reversing shaft A, which has two arms, $A\,B$ and $A\,C$,

on which, by means of the hangers Bc and Ce, the link and the valve-rod are suspended. The reversing shaft is moved by a lever placed in the cab, with which it is connected by the reach-rod G. When the motion has to be reversed from the position shown in the engraving, the link is lowered while the valve-rod is raised. With this link-motion a constant lead is not obtained. Its variations are, however, smaller than is the case with the Stephenson link. The Allen and Gooch links both require a great deal of space, to enable the eccentric and valve rods to be of the proper lengths, and this is their great disadvantage.

The Heusinger von Waldegg (also known as the Walshaert) valve-motion is used on the Belgian locomotives almost exclusively, and in America on the double-truck locomotives built by Mason. It is applied only on the outside. Its construction is shown in Fig. 2861. An eccentric K, fixed on

2861.



the axle vertically to the crank (without the angle of advance), by means of the eccentric-rod $O\,c$, imparts its motion to a link pivoted at its centre L. A block B can be moved in the slot of the link by means of the hanger $C\,B$, attached in the usual way to the reversing shaft A. The block is joined by a pin to the radial rod $B\,D$, which is pivoted at D to a lever $E\,F$. The lower end of the lever $E\,F$ is pivoted at F to the cross-head, giving thus a rocking motion to the lever, which at E is jointed to the valve-rod $v\,v$. To understand the action of this arrangement, we may imagine the crank-pin to be on one of the dead centres. In this position the eccentric, having no angle of advance, gives no lead to the valve; which is, however, obtained by the position of the lever $E\,F$, which at this moment stands at an angle to its central position. The rotation of the eccentric will impart a rocking movement to the link, which, acting on the valve-rod by means of the rod $B\,D$ and the lever $D\,E$, moves the valve. When the crank arrives at the second dead centre, the eccentric has left the valve in its middle position, but the lever $E\,F$ has carried it farther by its angular position from the other side of the central line, and has given the lead. All that is here necessary to effect a constant lead is to make the slot in the link curved with the radius equal in length to the radial rod $D\,B$. It is also advantageous to make the line $D\,L$ parallel to the line of motion.

On some European locomotives a separate cut-off valve is introduced, but it has never found any large application.

The shifting of the links or of the sliding blocks is usually accomplished by the *reversing lever*, which is always placed in the cab or on the driver's platform, and has its fulcrum at the lower and a handle at the upper end (see $O\,O$, Fig. 2843). This lever moves between two curved bars, $w\,w$, called quadrants or sectors, provided with notches by means of which, and of a latch moved by a trigger, the lever can be locked in certain positions; the notches correspond with different points of cut-off. Below the quadrants the reversing lever is pivoted with the reach-rod. To enable the engine-driver to adjust minutely the point of cut-off, the reach-rod ends sometimes with a screw-spindle, which is moved by a nut of a hand-wheel; this arrangement is largely employed in Europe.

The Running Gear.—Under this name is understood that portion of the locomotive which is the support for the boiler and the engines, and which could be properly called the wagon. It consists of frames, axles with wheels, and the intermediate parts which join the frames with axles, namely, axle-boxes and springs. The American truck, or "bogy," constitutes a separate, and, so to speak, additional part of the running gear.

The Frame.—The American and European frames are of entirely different construction. The former consists of two square-shaped wrought-iron bars, one on each side of the boiler, which extend the whole length of the locomotive, and project beyond both extremities of the boiler. (See $H\,H\,H$, Figs. 2842 to 2846.) If the locomotive is very long, these bars are made in two parts, securely bolted together. They are usually made straight from their back end until a short distance beyond the last driving-axle, where they are carried down to about the centre-line of the cylinders, having suitable recesses made to receive the cylinder castings. These bars are provided with vertical legs, two for each, and one on each side of the axle-boxes, which form so-called "jaws" or "pedestals." The two legs of each pedestal are jointed together at the bottom by a bar called a "clamp," fastened with bolts. The pedestals are stiffened by a brace (also a square-shaped bar, but lighter), which is welded to the legs of two neighboring pedestals at their lower ends. The outside legs of the two

extreme pedestals have their lower ends braced diagonally to the upper frame-bar. On account of its shape, this frame is called a "skeleton frame." The frames are fastened to the boiler at the fire-box by so-called "expansion pads," which are plates embracing them and bolted to the fire-box, so as to allow the boiler to slide on them longitudinally, providing thus for its free expansion. A solid joint is effected at the cylinders, and through the interval between them with the smoke-box. The cylinder-saddles, which are bolted with vertical and horizontal bolts to the frames, and are themselves solidly bolted together and with the smoke-box, form a very strong bracing between the frames, replace advantageously the transverse braces used for this purpose on many of the European locomotives. The yoke-braces are also fastened with angle-iron to the boiler, and sometimes extend across, joining the two frames.

One or more cross-braces (see *u''*, Fig. 2845), between the fire-box and the cylinders, join the frames together and with the boiler; and short vertical braces, *d'*, Fig. 2843, on each side, also connect the frames with the boiler. Each end of the frame is braced to the smoke-box at the fire-box back sheet, by round diagonal braces, as shown at *r'*, Fig. 2843; the latter are, however, disappearing from use. A wooden bumper *E'*, Figs. 2842 and 2843, as long as the greatest width of the locomotive, connects the frames at their front ends. The back ends of the frames are connected with a flat horizontal wrought-iron bar, which supports the cast-iron bed-plate or foot-board, *K' K'*, Fig. 2843, and the so-called "house-brackets," *A'' A''*, Fig. 2846, on which the cab *Y Y*, Figs. 2842, 2843, and 2846, is erected. At the bottom of the bed-plate is cast a pocket to receive one end of the draw-bar, where it is fastened by a pin *G'*, Figs. 2843 and 2846. Two check-chains, *X'' X''*, Fig. 2846, are attached to the cross-brace and the foot-board. These serve also to couple the engine with the tender. The frames on American locomotives are almost always placed inside of the wheels, and when they are outside their construction is the same. The European locomotive frames are always made of plates, seldom exceeding 1¼ in. in thickness, which are placed vertically, and have suitable openings cut out to receive the axle-boxes. (See illustrations of European locomotives in LOCOMOTIVES, CLASSIFICATION AND FORMS OF.) They are stiffened by cross-braces and angle-irons, attached to the fire-box in a similar way as in American practice, and only at the smoke-box are solidly joined to the boiler, by means of transverse braces. The latter are iron plates placed vertically across and bolted to the smoke-box and frames by means of angle-irons. The cylinders, if placed inside, replace such braces by being bolted to the frames and the smoke-box. Outside frames are not often used, as the two inches which would be gained by such arrangement, the only advantage from which would be the making of the fire-box that much wider, are not worth the increased difficulty in construction. But double frames, outside and inside, are still made, although they are disappearing, for the reason that they necessitate double axle-bearings, which, besides other inconveniences, do not wear uniformly. Cross-braces which are placed between the fire-box and cylinders are in Europe not fastened to the boiler, but are sometimes provided with brass slides, on which the boiler is supported. The front ends of these frames are jointed by a wooden or iron bumper, which latter consists of iron plates riveted to two channel-bars, forming thus a long hollow box, to which are attached a coupling hook and two spring buffers. The back ends of the frames are connected with vertical cross-plates. A horizontal plate placed on the top serves for a foot-board. The coupling arrangement between the European locomotive and tender usually consists of a draw-bar, or a hook of two links or rods, provided with screws and nuts by which they are fastened to corresponding rods of the tender, and of two check-chains. There are also other arrangements for coupling the locomotive with the tender in use. The draw-bars are usually provided with springs, to diminish the effects of sudden shocks or pulls; and two spring buffers are always attached to the back end of the European locomotive.

Locomotive Wheels and Axles are either driving or carrying. The latter, if attached to trucks—as is always the case in America—are called truck-wheels. The driving-wheels (*B' F'*, Figs. 2842 to 2846) consist of wheel-centres and tires. The wheel centres are in America made of cast iron, with hollow spokes, rims, and hubs, and are cast in one piece. The tires, usually of steel, are fastened on the centres by expanding them first by heat, and then allowing them to shrink on a centre, the outside diameter of which is made slightly larger than the inside diameter of the tire. A counter-balance weight is placed opposite to the crank-pin, which is either cast in the rim, or consists of plates bolted to the wheel-centres. The European driving-wheels, of wrought iron or steel, are a very difficult and expensive piece of work. They are fastened with tires, sometimes by shrinkage alone, but commonly by the addition of bolts and nuts. The tires are provided with flanges, to prevent the locomotive from leaving the track; their tread is not cylindrical, but conical. The driving-axles (*B F*, Figs. 2842 to 2846) are made of wrought iron or steel, pressed in the hubs of the wheels by hydraulic or other pressure, and are secured from getting loose by square keys. That part of the axle which is in the hub is in European practice always made the heaviest. Next comes the journal, which is separated from the central portion of the axle by a collar, to prevent a lateral slip of the axle-box. The centre has the smallest diameter. In American practice, the axle at the hub is usually made of a smaller diameter than at the journal, the object of this being to form a stop for the wheel when this is being pressed on the axle. On the main driving-axle *B* are fastened the eccentrics (see Figs. 2843 and 2845), which in Europe are forged in one piece with the axle, while in America they are made separate and fastened on the axles by bolts or screws. The main driving-axles are usually made of a uniform diameter, the whole length between the hubs.

The main driving-axles for inside-cylinder locomotives have the cranks forged in one piece with them, being thus expensive and more liable to break. This alone is the principal cause why the inside-cylinder locomotives are not popular in America. For the outside frames the axles have their journals outside, and need separate cranks, thus making the axles considerably longer. Such cranks are often made with long hubs, which serve at the same time for journals. The crank-pins are of wrought iron or steel, and are forced into their hubs. The former practice of making them of a

conical shape at the hub, and securing them with a nut, has disappeared. The carrying wheels of European locomotives are either of wrought iron or steel, and have steel tires. Their axles have either inside or outside journals, or both, according to the arrangement of frames. The American truck-wheels (*E E*, Fig. 2842) are of cast iron, and are either chilled on their treads (the same as car-wheels) or provided with tires.

The wheels standing on rails are the carriers of the whole weight of the locomotive, which rests on their axles; and as the axles revolve with the wheels, instead of being stationary as on ordinary road wagons, it is necessary to provide suitable bearings which can be lubricated, in order to diminish the friction and prevent heating. Locomotive axle-boxes are made for that purpose. They consist of cast-iron blocks with cylindrical holes, which fit on the axle-journals, being provided with semi-circular brass bearings (as a better wearing material). The portion directly under the axle is cut out, and for it a hollow box, called "oil-cellar," is substituted, which being fastened by bolts can be readily taken out, filled with waste and oil, and replaced. A cavity on the top, with a hole cut clear to the journal, serves also as an oil-receptacle. The axle-boxes are placed between the legs of a frame-pedestal, which are called "axle-guards." Vertical ribs cast on the sides of the axle-boxes, between which passes a leg of the frame-pedestal, prevent them from slipping laterally. As the frame is supported on the axle-boxes by springs, it follows that any shocks caused by the unevenness of the track will move it up and down, resulting in a wear either of the box or the pedestals, or both; giving thus a play or lost motion which is damaging. To prevent this, a cast-iron wedge, that can be moved up or down by means of a screw-spindle and a nut, is introduced between the box and the leg of the pedestal, on one side; and a fixed cast-iron plate, called a "shoe," is often introduced on the other side.

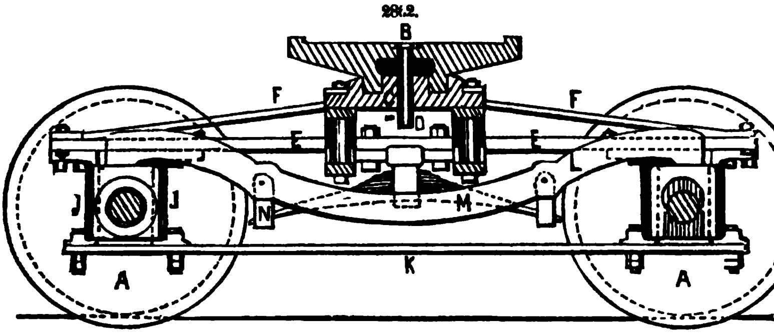
The springs are usually of the elliptical shape, and on American locomotives are placed above the axles. They consist of several steel plates, placed one on the other, the first of which is the longest, each subsequent one being shorter. The plates are held together by a wrought-iron band surrounding them, and are bent into a shape nearly that of an arc of a circle, with its concave side uppermost. A casting, called a "spring-saddle," or an iron bar bent in a suitable shape, stands on the axle-box and supports the spring at its centre, the frame passing between its legs, where a play is given to admit of vertical motion. The frame is suspended on springs from their ends, on so-called "spring-hangers," which are either single bars passing through slots made for this purpose in the frames, or double bars passing on both sides of the frame. At the lower end of the hangers is attached a casting which, through an India-rubber plate, supports the frame. In Europe the springs are attached either to the top or the bottom of the axle-boxes. The hangers are riveted or bolted to the frame at the one end, while at the other end they are provided with screw-spindles and nuts, which admit of regulating the load on the springs. Spiral springs are seldom used.

To divide the loads on the axles equally, equalizing levers are introduced, which are always used on American locomotives, and to some extent also on European ones. The equalizing lever (see *f f*, Fig. 2844) consists of a horizontal bar, placed between two axles, the ends of which are suspended on two hangers of the neighboring springs. In its centre, by means of a stand, also called a "fulcrum," which is bolted to the frame, rests the weight of the locomotive, namely, that portion of it which loads the two axles. The fulcrum, being exactly in the centre, divides the weight equally on both springs or the axles. The effect of shocks to any of the wheels, when passing a rail-joint, etc., is also immediately transmitted to both springs, thus producing much easier motion.

The eight-wheeled American locomotive, like the one illustrated here, is thus supported in two points at the back end, and, as we shall explain presently, at only one point in its front end, constituting thus a three-point support which is advantageous.

Trucks.—Excepting the switching locomotives, and in some few other rare cases, all American locomotives are provided with trucks, which are their most characteristic feature. The truck admits of

2862.



running on very sharp curves, notwithstanding a long wheel-base, with steadiness and a degree of safety unequaled by other locomotives. There are several kinds of trucks. The ordinary four-wheeled centre-bearing truck is shown in Figs. 2862 and 2863, representing respectively its longitudinal and cross sections. It consists of four wheels, *A A*, which are either composed of cast-iron centres with steel tires, or oftener are of the chilled cast iron used on American cars. Their axles are provided with inside journals, carrying boxes of a similar construction as those of the driving-axles; on each two boxes of the same side of the locomotive are supported two iron bars *L*, called equalizers, on which elliptical springs *M*, carrying the whole weight which is placed on the truck, are

suspended by means of hangers N attached to the equalizers by pins. The spring-hangers are equally distant from the centre of the equalizers, which is also the centre of the spring. In this way equal weights must fall on each of the axles.

It remains now to describe how the weight of the locomotive is placed on the springs. For this purpose the cylinder-saddles are securely bolted to a casting B, called the upper centre-plate. This upper plate rests on the lower centre-plate C, which is bolted on the truck-frame. The forms of the centre-plates are such that they can move independently of each other around the common centre. This arrangement admits of the truck taking a position almost tangential to the curvature of the track, and thus facilitates the movement of the locomotive on curves. A centre-pin passes through the centre of both the plates, and, having a head on the top and a key put through it at the bottom, prevents the truck from being separated from the locomotive in case of leaving the rails. The truck-frame E is of rectangular form, and forged in one piece. The centre-plate is attached to it by means of two longitudinal bars F and two transverse bars G. The bars G are trussed by two other bars H, Fig. 2863, all being bolted to the frame and connected with the centre-plate by bolts. The frame rests on the springs, and is provided with legs J, which form the pedestals for the axle-boxes. No provision is made for the wear of these, as is the case on the pedestals of the driving-axles. Braces K unite the pedestals at the bottom.

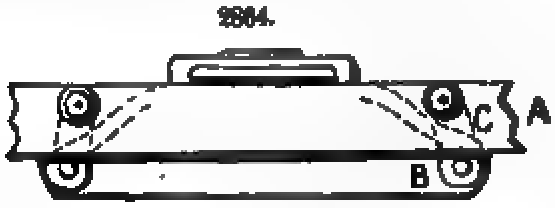
2863.

The truck as described admits only of the wheels moving around a centre which cannot leave the centre-line of the locomotive, but it is easily understood that when the truck enters a curve it has a tendency to move also laterally; that is, its centre has a tendency to leave the centre-line of the whole locomotive, and approach the radial centre of the curvature. To satisfy this tendency, the Bissell truck has been invented, which is so arranged that the lower centre-plate, instead of being bolted to the frame, is allowed to slide on it laterally, a suitable plate bolted to the frame forming the bearing surface. In order that the transverse centre-line of the truck may assume a radial position to the curve, the truck-frame is attached to a bar, called the radial bar, the other end of which is pivoted on a fixed centre, at a distance back from the truck. The "swing-truck" is an improvement on the Bissell truck, and is regarded as the best device of the kind in use. In this, in place of the friction arrangement, the lower centre-plate A, Figs. 2864, 2865, and 2866 (representing the side view, plan, and cross-section of the swinging arrangement), has cast upon it extension B, the ends of which are suspended on links C, called suspension-links. These links are attached to two diagonal bars A, fastened to the truck-frame. It is evident that by such arrangement the centre-plate, swinging on the hangers, can move laterally on the truck, which is thus independent of the centre-line of the locomotive.

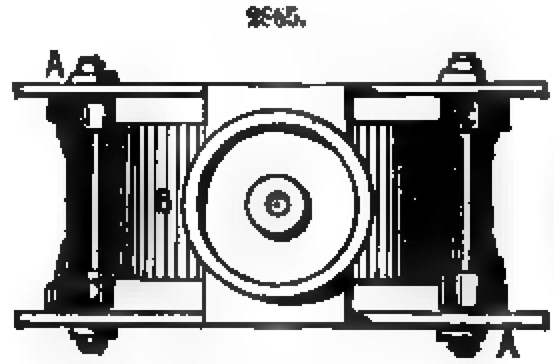
There are also two-wheeled trucks, which are usually made swing-trucks by a similar arrangement to that above described, and which require a radial bar, as otherwise they would only be pushed laterally by the curvature of the rails, without moving around the centre, as is necessary in order to have the axle take a radial position.

Trucks are now (1879) not much used in Europe, though they are gradually being introduced. To enable European locomotives to run on curves, their wheel-bases are made short, and a lateral or

2864.



2865.



2866.

radial slip is allowed between the axle-boxes and the axle-guards on the two extreme ends. Should the latter be driving-axles, a play between the stub-ends and the shoulders of the crank-pins is also given.

The Pilot.—American locomotives are provided in front with a "pilot" or "cow-catcher," S, Fig. 2842, made either of wood or iron, the object of which is to clear the track from obstructions. It consists of a rectangular vertical frame, the upper side of which is fastened to the bumper, and the bottom side constitutes the base of a horizontal triangular frame, with its point in front. The two sides are connected with the upper side of the vertical frame by bars, which give to the pilot a shape

similar to that of a plough. In Europe, in place of the pilot, two bars are attached to the bumper, which are carried down to within a short distance from the rail, and serve the same purpose as the pilot. To the pilot, or directly to the bumper, is attached a bar Z', Fig. 2843, which is pivoted on a casting, and is called the "push-bar," as it serves to push the train that may be coupled on in front of the engine.

Sand-Box.—On the top of the locomotive, or in some other convenient place, is the sand-box, V, Fig. 2843. This is a cylindrical box, placed on a cast-iron base, and provided with a cover. It holds the sand which is used to increase the friction between the rails and wheels in case the latter slip. For this purpose sand is carried from the box through pipes, which can be opened or closed by valves operated by a rod from the cab. The pipes extend to within a few inches of the rails, and deliver the sand directly under the wheels.

American locomotives are always provided with *bells*, U, Fig. 2842, placed on the boiler in the neighborhood of the smoke-box, which are rung by a rope from the cab. Their object is to give warning of the approach of a locomotive.

The *head-light*, T, Fig. 2842, is a large lamp with a very powerful reflector, which serves to throw the beam a long distance on the track in front of the locomotive. The head-light is attached to the upper part of the smoke-box on brackets.

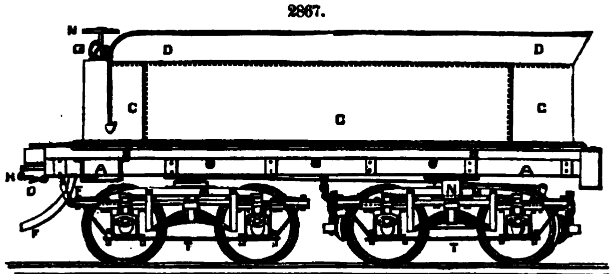
A *cab* (see $Y\ Y$, Figs. 2842, 2843, and 2846) is always placed on the American locomotive. It is usually made of wood, with windows all around, and doors in front leading to the running-boards. It is supported on so-called "house-brackets," $A''\ A''$, Fig. 2846, of cast iron, which are fastened to the back-end cross-brace and the frames. Steps $q'\ q'$, Fig. 2842, attached to rods suspended from house-brackets, afford easy access to the interior.

The *running-boards*, $i\ i$, Figs. 2842 and 2845, are narrow wooden boards, one on each side of the boiler, to which they are attached by brackets. They extend from the cab to the smoke-box. An iron plate, D', Figs. 2842 and 2844, placed on the frames in front of the smoke-box, called the "front platform," allows an attendant to walk around the locomotive while the latter is in motion.

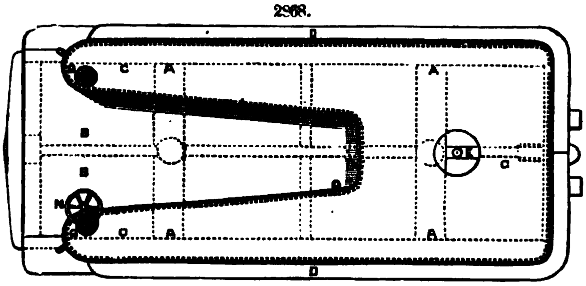
Brakes are attached to locomotives, and may be either separate or in connection with the continuous brakes of the train. (See BRAKES.)

THE TENDER.—In order that the boiler may be constantly fed with water and fuel while the locomotive is in motion, a supply of both is usually carried in a separate vehicle behind the locomotive, called the "tender." Locomotives designed for exceptionally heavy work, which require a great load on their wheels, carry their own supply, and therefore are called "tank locomotives." The tender consists of a frame supported on two trucks (resembling a platform car), having a water-tank and a space for coal on its top. The American tender is represented in side elevation and plan in Figs. 2867 and 2868. The frame, $A\ A$, is usually made of wood, but sometimes of channel-iron. Its construction is similar to that of a freight-car frame. The tender-trucks differ from engine-trucks principally in having outside axle-journals and no swing motion. They are either of wood or of iron, and are represented as of iron in the engravings. To apply in this instance the principle of the three-point support, the trucks are often so arranged that the one in front supports the frame on the centre-plate, while the hind truck has two castings, $N\ N$, one on each side, on which the frame rests. On this account the first truck is called the "centre-bearing," and the second the "side-bearing." Many engineers prefer to have both trucks side-bearing. This is a safer arrangement, as in case a wheel of the first truck should break, the side-bearings will prevent it from tipping down. The tender axle-boxes are similarly constructed to those of a car. (See RAILWAY CARS.) The tank, $C\ C\ C$, is constructed of thin sheet iron, in the shape of a horse-shoe, to make room for fuel. The sheet-iron rim $D\ D$, at its upper edge, prevents the fuel from falling out. The sheets of the tank are stiffened with angle-iron, and sometimes the opposite sides are braced with rods. The body of the tank, being wider than the frame, requires cast-iron brackets to be bolted to the longitudinal members of the frame. The floor-timber which covers the frame extends over these brackets, projecting beyond the tank, which is placed on it. The tank is secured on all sides from slipping by wooden mouldings, which are nailed to the floor, and also by a few wrought-iron ears, riveted to the tank and bolted to the frame. The tank is filled with water by a round hole, E, called the "man-hole," as it is made always large enough to admit a man

2867.



2868.



to clean the inside of the chamber. This hole has a sheet-iron neck, or a cylinder riveted around it, on top of which is placed a cover. The water from the tank is conducted to the locomotive pumps, or injector supply-pipes, by rubber hose $F F$, which is attached to the bottom of the tank, at both its legs in front. By means of valves, operated by handles $G G$, the openings through which the water flows from the tank to the hose are closed or opened. Strainers perforated with holes prevent the dirt from entering the pipes. The draw-bar H and two safety-chains $d d$ are used for coupling the tender with the locomotive. Every tender is provided with a hand-brake operated by a wheel N.

The European tender differs from that just described in having a sheet-iron frame, constructed similarly to the locomotive frame, and two or three rigid axles. The frames are braced by several vertical cross-sheets, uniting them, and the tanks are usually fastened by being both riveted to angle-iron. The three-point support is also sometimes effected here by the use of only three sets of springs, two of which are placed between the two first axles, and the third crosswise on the hind axles. A glass water-gauge, or some other arrangement that shows the height of water in the tank, is usually attached to a European tender.

To enable a locomotive tender to take in water while running, Mr. Ramsbottom has devised an apparatus consisting of a pipe attached to the bottom of the tank, with its upper end curved near the top of the tank, so as to discharge the water downward. To its lower end, on a transverse centre-bearing, is attached a scoop or dip-pipe, with a rectangular mouth directed to the front, and counterbalanced so that when not in use it is tilted up clear of the ground. A wooden or iron water-trough is laid on the track between the rails, with its water-level about 2 inches higher than the top of the rail. In this the scoop is immersed about 2 inches under the water-level, when it is dropped in. These troughs are placed at points of the road where the tenders require to be supplied with water. On reaching a trough the fireman dips the scoop by means of a lever, and holds it down until sufficient water has passed up into the tender. This is shown either by the water-gauge, or by the discharge of water through the man-hole. The principle of action of this apparatus is based on the law that the height to which a body can be raised is proportionate to the square of its velocity. The height to which water can be raised is thus proportionate to the square of the speed of the train, the action being the same whether the scoop is stationary and the water moves, or *vice versa*. It being known that a body thrown with the velocity of 32 feet a second will rise at the end of the first second to a height of 16 feet, it follows that the water will be forced to this height with a corresponding speed of the train, which is nearly 22 miles per hour, and to nearly 30 feet with a speed of 30 miles. The theoretical quantity of water delivered is the cubic contents of the channel made by the mouth of the scoop and the length of its passage. This quantity is found to be obtained at a speed of about 33 miles per hour; but the differences are slight for all speeds above 22 miles per hour, when nearly the full theoretical quantity is obtained. T. F. K.

LOCOMOTIVE, INTERNAL DISTURBING FORCES OF THE. Under this name are understood only those forces which are caused by the construction of the locomotive itself, and are not influenced by any outside causes, as for instance the condition of the track. These forces are the result of the action of the steam in the cylinders, of the reciprocating or rotary movements of the masses, of the thrust of cross-heads on the guide-bars caused by the angularity of the connecting-rods, and of the action of the tractive force. They cause disturbing movements to the locomotive which are of two kinds: movements of the upper portion of the locomotive, i. e., of that portion which is suspended on the springs; and movements of the whole locomotive, axles and wheels included. Movements of the first kind are: 1. Uniform rise and fall; 2. Oscillation in regard to a horizontal axis parallel with the track, and passing through the centre of gravity; 3. Oscillation in regard to a horizontal axis perpendicular to the track, passing through the centre of gravity, which motion is sometimes named the overbalancing motion. Movements of the second kind are: 1. Periodical forward and backward movement (parallel with the track) during each revolution of the wheel; and 2. Oscillating motion with regard to a vertical axis passing through the centre of gravity, due to the play between the rails and wheel-flanges. Only such of the disturbing forces as are caused by the movement of the reciprocating and revolving masses can be neutralized by the application of the counterbalance weights to the driving-wheels. Movements due to the thrust of the cross-heads can be diminished by increasing the wheel-base, by placing the cylinders nearer to the centre of the locomotive, so that the centre-line of the two cross-heads in their middle position would pass through the centre of gravity, and by increasing the lateral distance between the axle-springs. The position of the coupling-bar which unites the locomotive with the tender, and through which the tractive force is transmitted if placed above the centre of the axles, causes a partial unloading of the hind axle and overloading of the front axle; and any variation of the tractive force will thus cause a motion to the upper part of the locomotive. The position of the cylinders, whether inside or outside, has an influence on the disturbing motions of the whole locomotive. The greatest stability is obtained if the cylinders are inside, the coupling-rods outside, and the main and coupling crank-pins opposite to each other. Le Chatelier was the first who applied counterbalance weights to locomotive driving-wheels, with the object of destroying the disturbing effects of the momentum of reciprocating parts.

The following are formulæ by which the amount of the counterbalance can be determined: *

$$G = \frac{R}{r}\left(Q\frac{s+e}{2s} \pm Q'\frac{e'+s}{2s}\right), \text{ and } G' = \frac{R}{r}\left(Q\frac{s-e}{2s} \mp Q'\frac{e'-s}{2s}\right)$$

where e is half the distance between the cylinder-centres, and also between the centres of gravity of the reciprocating parts acting on the main driving-wheels; e', half the distance between the centres of gravity of the reciprocating parts acting on the coupled wheels; s, half the distance between the rails or the centres of the wheels; Q, the weight of the moving unbalanced parts acting on the main

* Heusinger's "Locomotivbau," p. 192.

crank-pins (these are pistons and cross-heads with their attachments, main connecting-rods, main crank-pins, and the cranks the weight of which has to be referred to the centre of crank-pins); Q', the weight of the moving, unbalanced parts acting on the coupled crank-pin or crank-pins (these are parallel rods, crank-pins, and cranks referred to the crank-pins); G, the weight of the counterbalance attached to the main driving-wheels; G', the weight of the counterbalance attached to the coupled wheels; R, the radius of the crank; and r, the distance of the centre of gravity of the counterbalance weight from the centre of the axle. The second factors of the formulæ are to be taken with the upper signs if the main and the coupling crank-pins are placed on the same side of the centre of the axle (as in all outside-connected locomotives), and with the lower signs if these crank-pins are placed opposite each other in regard to the centre of the axle. The counterbalance weights are commonly determined by adding equally divided parts of the reciprocating weights to the unbalanced revolving parts of each wheel, which are then the weights acting on each crank-pin requiring to be balanced. Multiplying these weights by the radius of the crank and dividing them by the distance of the centre of gravity of the counterbalance, the result will be the weight of the counterbalance. T. F. K.

LOCOMOTIVE, PROPORTIONS OF THE. In designing a locomotive, it is necessary first to know the weight of the train to be hauled, the speed at which the engine must run between stopping-places, and the profile and the plan of the road on which it is to work. With these data given, the size of the locomotive can be ascertained, and the power and adhesion can be calculated. Often only the steepest grade and the curve which may accompany it are given; and if the grade be long, the speed with which the train has to run on it is also given. From these data the maximum capacity of the locomotive is ascertained. But to produce an economically-working locomotive, the best plan is to calculate also the mean average tractive force which the locomotive has to exert while running the whole distance of the road where it has to work. This can be accomplished with the help of the formulæ given for calculating the train resistances, by multiplying the resistances on each different section of the road by its length, adding the results together, and dividing their sum by the total length of the road. This will give the average resistance. In these calculations the local meteorological conditions should not be overlooked, as the nature, direction, and force of prevailing winds give rise to important factors in the resistances, and the humidity of the air influences the adhesion. Having also found the maximum resistance of the train (in which it is best to include the tender, whose size is usually known near enough beforehand), the adhesive weight of the locomotive necessary to overcome it may be ascertained if the coefficient of adhesion is known. Under ordinary circumstances in America, a coefficient of one-fifth is sufficient for the purpose; but under special circumstances, if the locomotive is to run in a tunnel or a mine, or in a locality where rain and fog prevail throughout the year, this coefficient has to be first determined. As a general rule, also, multiplying the maximum resistance in pounds by 5 will give the adhesive weight of the locomotive necessary to overcome the train resistance. The type of the new locomotive is usually also known, and with it the proportion of the dead weight (weight carried by the truck or the running wheels) to the total weight of the locomotive. If it be, for instance, the standard American locomotive, the dead weight is one-third of the total, or one-half of the adhesive weight. Adding thus 50 per cent. to the adhesive weight obtained by the foregoing calculation, a total weight of the locomotive is found which would be sufficient to overcome the train resistance alone. As the locomotive has to overcome also its own resistance, we have to add this to the train resistance, and a total resistance will thus be obtained, from which the adhesive weight of the locomotive, and also its total, can be calculated. A correction will still have to be made, as the resistance of the locomotive has been taken for a smaller weight than the actual. The final result will give a locomotive with sufficient adhesion to overcome the maximum resistance, without admitting of the wheels skidding under ordinary circumstances.

The number of axles is determined from the weight of the locomotive, allowing a maximum of 12 tons on a driving-axle (although this limit is sometimes greatly exceeded by some European designers), and about half that weight on a truck or running axle.

The diameter of the driving-wheels depends upon the speed at which the locomotive is to run. Passenger locomotives have larger driving-wheels than freight locomotives, and in America the former are usually made from 5 ft. to 5 ft. 6 in. in diameter, and the latter from 4 ft. to 5 ft. On mountain locomotives or for narrow gauges they are made smaller than indicated by the above limits. In Europe passenger locomotives have larger driving-wheels than in America, while the freight locomotives have smaller ones. The stability of the locomotive, depending upon the number of revolutions that the driving-wheel is making in a unit of time, gives the lower limit to the size of the driving-wheels. Thus the larger the diameter of the driving-wheel, the higher will be the speed at which a locomotive can be allowed to run. There is, however, an obstacle to making large driving-wheels, as they necessitate an elevation of the boiler above the rails not at all favorable to stability, and they also augment the weight of the wheels. The American passenger locomotive makes from 150 to 250 revolutions per minute, and the freight locomotive from 100 to 200. The diameter of the driving-wheels being given, or ascertained within the limits in regard to the number of revolutions which practice has shown as admissible, the size of the cylinders can be found by calculation. The tractive force which the locomotive has to develop must be sufficient to overcome the total resistance of the whole train; and as it depends not only upon the size of the cylinders, but also upon the steam-pressure on the piston, this has to be determined at first.

Locomotive boilers are usually built to carry from 125 to 135 lbs. of steam-pressure per square inch, as shown by the gauge; but this whole pressure is probably never obtained in the cylinder during the admission, as friction, wire-drawing, and condensation will reduce it by about 10 to 20 per cent. of the boiler-pressure. To use the steam economically, the cylinders have to be made large enough to admit of expansion, and on locomotive engines good results are obtained if the cylinders are made sufficiently large to develop a force equal to the average resistance of the train (as cal-

culated above) with an admission of steam of one-third of the stroke on passenger locomotives, three-eighths of the stroke on freight locomotives, and up to one-half on mountain locomotives. To find the average effective steam-pressure on the piston, the following table, which has been calculated by a formula given by Poncelet,* and where the average back pressure on the pistons has been taken equal to 7 lbs., will be found convenient:

Admission in per cent. of the stroke	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{2}{3}$	$\frac{3}{4}$
Average steam-pressure in per cent. of the admission of steam-pressure	31.7	38.2	46.7	58.5	63.4	75.4	83.6	85.7	90.0

A greater admission than three-fourths of the stroke should never take place; and if the size of the cylinders, after being determined as sufficiently large to give a tractive force equal to the average resistance with the admission as given above, should not be sufficiently large to overcome the maximum resistance with an admission of three-fourths of the stroke, they would have to be made proportionately larger. The size of the cylinders is determined by the stroke of the pistons and the diameter. The length of the stroke is limited by the piston-speed, which is on passenger locomotives 700 to 1,000 ft. per minute, and on freight locomotives 400 to 700 ft. The speed of the piston can be found by multiplying the number of revolutions of the driving-wheels by the double piston-stroke. According to the speed of the locomotive and the diameter of the driving-wheels, the stroke is thus determined. The stroke is also limited by the crank, the pin of which can be placed only at a certain distance from the rim or the hub of the wheel. The diameter of the driving-wheels, length of the stroke, and average steam-pressure being known, the diameter of the cylinders is found from the formula given for the tractive force (see LOCOMOTIVE—TRACTION, etc.), and which can be written

$$d = \sqrt{\frac{P D}{p s}};$$

where d is the diameter of the cylinder, P the tractive force required, D the diameter of the driving-wheels, s the stroke, and p the average effective steam-pressure per square inch of the piston. If the resistances caused by the friction of the steam-engine mechanism, as that of the slide-valves, pistons, etc., are not included in the calculation of the resistance, they should be taken into account in the above formula for calculating the diameter of the cylinder, by substituting for p its value multiplied by a coefficient of the effect, which varies according to the grade of expansion, and may be taken at 0.75 to 0.80 for an admission of one-fourth to three-fourths of the stroke.

The dimensions of the boiler are determined by the amount of steam consumed per hour, which can be calculated by taking the contents of the cylinder from the beginning of the stroke until the admission is closed, adding to it the contents of the steam-port and the play of the piston, multiplying the result by 4 and by the number of revolutions in an hour. The weight of this steam can be found by multiplying its volume in cubic feet by the weight of a cubic foot of the saturated steam under a pressure corresponding to the admission-pressure in the cylinder, which will represent the weight of the water evaporated in the boiler per hour. From 15 to 16 per cent. more should be added for losses which result from a portion of water being carried off by steam, and from leakage. One square foot of heating surface will evaporate from 8 to 12 lbs. of water per hour; but the evaporation may be more than this, it depending largely upon the proportion of the grate to the heating surface. The heating surface is divided into the direct heating surface, or that of the fire-box, and the indirect heating surface, or that of the tubes. The amount of the direct heating surface is usually dependent upon the size of the grate and the number of tubes which determine the height of the fire-box; but special fire-boxes have also been constructed with the object of increasing this surface, by introducing water-partitions or combustion-chambers, it being generally believed that the direct heating surface is much more productive than the other. Recent experiments made by Mr. S. Verderber,† on the Hungarian State Railway, have shown an equal evaporation in two locomotives, both of the same type, but one with the regular fire-box and the other with its inside shell replaced by a non-conducting fire-proof material. This would prove that the fire-box heating surface is not at all necessary in a locomotive boiler as a steam-producer, and is an argument against the great importance which is generally attributed to it. The proportion of the direct heating surface to the total is usually in European boilers one-thirteenth to one-twelfth, which increases to one-eighth on American locomotives.

The area of grate is determined by the amount of coal which is burned to evaporate the necessary quantity of water. It depends thus on the qualities of the fuel, or rather the amount of water evaporated per pound of fuel, and the amount of fuel burned on a square foot of grate per hour. A pound of coke or coal will evaporate from 6 to 8 lbs. of water, in the average, in a locomotive boiler, and about 110 lbs. of coal or coke can be burned on a square foot of grate per hour. In Europe one square foot of grate area is given to about 80 feet of heating surface, while in America the grate area is made from one-seventieth to one-fortieth of the heating surface. The open space of the grate is usually made one-fourth to one-third of the total area.

There are three kinds of fire-boxes to be distinguished, according to the fuel they burn. The wood-burning fire-box requires only a small grate area, but the fire-box has to be made large enough to receive the quantity of wood that has to be burned. It is thus made deep and sufficiently large,

* $p = k p'' - p'$. where p is the average effective pressure on the piston, p'' the absolute pressure of admission steam. p' the absolute back pressure, and k a coefficient.

† *Oesterreichische Eisenbahn-Zeitung*, February 2, 1879; *Railroad Gazette*, 1879.

and dead-plates are introduced in it, which are usually placed around the inside shell, leaving a comparatively small grate-area between them. Fire-boxes for burning bituminous or soft coal require larger grates provided with a rocking or shaking arrangement. Air has to be often introduced above the grate, to afford more perfect combustion, and fire-brick arches or water-tables are valuable additions. The anthracite-burning fire-box is made long and hollow, and has a water-tube grate, to prevent melting on account of the intense heat. A new kind of fuel has lately been introduced on railroads, which is the very fine coal heretofore considered as waste. Fire-boxes for this fuel are shallow, and require very large grates.

Rules from which to ascertain the different proportions of boilers for the various kinds of fuel cannot be given, but the following proportions used by Mr. W. S. Hudson will represent the average American practice:

DETAILS.	Wood-burning.	Bituminous-coal burning.	Anthracite-coal burning.
Size of cylinders	16 × 24	16 × 24	16 × 24
Heating surface of tubes in sq. ft.	886.95	904.05	894.47
Heating surface of fire-box in sq. ft.	85.23	92.02	100.86
Total heating surface in sq. ft.	972.18	996.07	995.83
Ratio between heating surface in sq. ft. and the cubic contents of one cylinder in ft.	848.20	860.69	856.49
Area of grate (dead-plates included) in sq. ft.	14.29	15.41	22.07
Ratio between heating surface and grate-area	68.03	64.70	45.08
Area of dead-plates in sq. ft.	9.00	0 to 2.5	......

From experiments on the Baltimore and Ohio Railroad, the following gives the comparative value of the three kinds of fuel:

Amount of Fuel consumed on the Baltimore and Ohio Railroad, at different periods from 1833 *to* 1848.

DATE.	Weight of Engine on Driving-Wheels.	Position of Boiler.	Gross Loads.	Miles Run.	Fuel Consumed.
1833	4 tons.	Upright.	23 tons.	80	1.15 tons anthracite.
1834	7.5 "	"	45 "	80	1.25 " "
1838	8.5 "	"	50 "	60	1.5 " "
1840	10.5 "	"	60 "	60	1.25 " "
1840	10.5 "	"	60 "	60	1 " bituminous.
1841	9.75 "	"	60 "	80	1.65 " "
1841	6.5 "	Horizontal	40 "	80	2.05 cords of wood.
1841	19.33 "	Upright.	140 "	80	3.13 tons bituminous.
1841	8.25 "	Horizontal.	60 "	80	3.13 cords of wood.
1845	23.5 "	"	225 "	80	3.25 tons bituminous.
1848	10.5 "	Upright.	60 "	80	1.25 " "
1848	10 "	Horizontal.	60 "	80	1.08 " "
1848	10 "	"	60 "	80	2.75 cords of wood.
1848	10 "	"	60 "	80	1.58 tons of coke.
1848	23.5 "	"	200 "	80	2.25 " bituminous.
1848	23.5 "	"	275 "	98	2.5 " "

1 ton of bituminous coal = 1.25 tons anthracite coal.
1 ton of bituminous coal = 2.12 cords of wood.
1 ton of anthracite coal = 1.75 cords of wood.

The following account of the performance of locomotive boilers is taken from a paper by D. K. Clark: "The evaporation of 12 lbs. of water per pound of pure coke was found, by careful laboratory experiments, to be the maximum of evaporative performance. In the best ordinary practice an actual evaporation of 9 lbs. of water per pound of coke, or 75 per cent. of the possible maximum, was readily obtained, the balance being lost by leakage of air and by waste; and it was adopted by the author as the ordinary standard of practical economical evaporation. A minute analysis was made of the results of numerous authenticated experiments on the evaporative power of locomotive boilers, of various proportions, on the engines of the Caledonian, Edinburgh and Glasgow, and Glasgow and Southwestern Railways. It was concluded that the economical evaporative power of boilers was materially affected by the area of the fire-grate, and by its ratio to the whole heating surface; that an enlargement of the grate had the effect of reducing the economical evaporative power, not necessarily affecting the quality of combustion in any way, but governing the absorbing power of the boiler, as the lower rate of combustion per foot of grate due to a larger area, in burning the same total quantity of fuel per hour, was accompanied by a reduced intensity of combustion, and by a less rapid transmission of heat to the water, in consequence of which a greater quantity of unabsorbed heat must escape by the chimney. An increase of heating surface, again, reduced the waste of heat, promoted economy of fuel, and added greatly to the economical evaporative power. In short, the question resolved itself into the mutual adjustment of three elements—the necessary rate of evaporation, the grate area, and the heating surface, consistent with the economical generation of steam at the assumed practical standard of 9 lbs. of water per pound of good coke. An investigation of the cases of economical evaporation, in the 'Table of Experiments,' conducted the author to the following important equation, expressing the relation of the three elements of boiler-power; in which c was the maximum economical evaporation, in feet of water per foot of grate per hour, h was the total heating surface in square feet, measured inside, and g was the grate-area in square feet: $c = .00222 \frac{h^2}{g}$. From this it followed: 1st, that the economical evaporative power decreased directly as the area of grate was increased, even while the heating surface remained the same; 2d, that it

increased directly as the square of the heating surface, when the grate remained the same; 3d, that the necessary heating surface increased only as the square root of the economical evaporative power; 4th, that the heating surface must be increased as the square root of the grate-area, for a given evaporative power. It was contended thence that the heating surface would be economically weakened by an extension of the grate, and would be strengthened by its reduction; and that whereas large grates were commonly thought to be an unmixed good, and being generally recommended were usually adopted, still they might be made too large—not that their extension affected the quality of combustion, but that the economical evaporative power might be reduced. Concentrated and rapid combustion was alike the true practice for the largest and the smallest boilers; and in locomotives, where lightness, compactness, and efficiency were primary objects, the boilers should be designed for the highest average rate of evaporation per foot of grate that might be followed in good practice, consistently with the highest average rate at which coke could be properly consumed; as, in this manner, the smallest grate and the smallest amount of heating surface consistent with good practice might be employed. It was stated that 150 to 160 lbs. of good sound coke could be consumed per foot of grate per hour; and, allowing for inferior fuel, an average maximum of 112 lbs. per foot of grate was recommended as a general datum. This determined the average maximum of economical evaporation to be 16 ft. of water per foot of grate per hour, allowing 9 lbs. of water per pound of coke; for which 85 ft. of heating surface per foot of grate should be provided. It was accordingly recommended that a heating surface at least 85 times the grate-area should be adopted in practice.

"Such experiments as 'midfeathers,' etc., which were resorted to for specially increasing the fire-box surface, were condemned, as they were considered to be no better than tubes, while practically they were inconvenient and costly; as, among other reasons, plates of seven-sixteenths of an inch or half an inch in thickness were employed to do the work of the tubes, which were less than one-eighth of an inch in thickness.

"A practical rule followed by some engineers, and stated to be founded on extensive experience, was to allow 5 ft. of heating surface for 1 ft. of water evaporated per hour, and 100 ft. of evaporating surface per square foot of grate. Those results were found to agree with the maximum rates recommended in the paper. It was also argued that the intensity of combustion materially affected the amount of heating surface necessary for economical evaporation, being less as the intensity was greater. It was contended, on the other hand, that the formula as stated in the paper would not apply to all engines. It was further argued that, from various causes, no formula could be framed to be of service unless all the circumstances in each case were properly taken into account.

"As an example of the objections to long tubes, the results were given of the work done by a luggage engine on the London and Northwestern Railway, before and after alteration. That engine originally had tubes 14 ft. long, with a total surface of upward of 800 ft.; the length of the tubes was diminished to 4 ft. 9 in., and the total surface was reduced to about 500 ft., when it was found that a saving in fuel of 40 per cent. per ton per mile moved was produced, with a saving of 23 per cent. per mile run; the coke used per ton per mile, with long tubes before alteration, being .504 lb., and with the short tubes, .298 lb.

"The back pressure was contended to be a serious drawback to the long-tube engine, and an example was given of a trial of a single engine on the new plan, against two of the ordinary kind, of 170 tons in both cases; and, although the single engine was 43 per cent. less powerful than the two engines together, and had 20 per cent. less heating surface, yet it had performed the same distance of 111 miles in 10 minutes less time, and with 8 lbs. per mile less fuel. This, it was argued, was owing to the engine exerting a greater dynamic force by being relieved from the back pressure of the blast-pipe, which in the case of the other two was applied to force the fire, and to draw the heated air through the long tubes.

"By the mode of placing the tube-plate some distance within the cylindrical part of the boiler, the tubes were not liable to be choked with cinders, or the draught to be obstructed. This plan also afforded an opportunity of reducing the size of the tubes from $1\frac{3}{4}$ inch diameter to $1\frac{3}{8}$ inch, giving in the same boiler an equal area of flue passage, while the proportion of tube heating surface was increased 34 per cent. per foot of length of tube, and a very large addition of flame surface was gained.

"As to the evaporative powers of marine boilers as compared with those of the best locomotive boilers, if an investigation was instituted it would be found that the general features of the best tubular marine boilers now used in ocean navigation were nearly identical with those of locomotive boilers, but the circumstances under which they were used were very different. In the marine boilers, coal was used instead of coke, and the natural draught of the chimney, instead of the urging of the blast-pipe in a locomotive, worked for many weeks or months consecutively, without the means of stopping for any extensive repair, or even to be cleaned except at long intervals. The following statement showed the comparative proportions and effect of the two descriptions of boilers:

In the Locomotive Boiler—	*In the Marine Boiler—*
1 square foot of fire-grate consumed about 112 lbs. of coke per hour.	1 square foot of fire-grate consumed about 20 lbs. of coal per hour.
1 square foot of fire-grate required about 85 square feet of fire-box and tube surface.	1 square foot of fire-grate required about 30 square feet of fireplace and tube surface.
1 square foot of fire-grate with the above surface would evaporate 1,008 lbs. of water per hour.	1 square foot of fire-grate with the above surface would evaporate 170 lbs. of water per hour.
1 square foot of flue surface would evaporate 11.7 lbs. of water per hour.	1 square foot of flue surface would evaporate 5.66 lbs. of water per hour.
1 lb. of coke would evaporate 9 lbs. of water.	1 lb. of coal would evaporate 8.5 lbs. of water.
1 H. P. of 33,000 lbs. lifted 1 foot high per minute, required about 4 lbs. of coke per hour.	1 H. P. of 33,000 lbs. lifted 1 foot high per minute, required about 4.25 lbs. of coal per hour.

"From this statement it appeared that, although the proportion between the fire-grate and the flue surfaces was widely different, the quantity of water evaporated and the power obtained by the consumption of a given weight of fuel were nearly the same, when allowance was made for the difference in the evaporative power of coal and coke. The possible maximum evaporative power of 1 lb. of carbon was deduced from the results of chemical experiments, showing that 1 lb. of carbon, converted into carbonic acid, developed 14,000 units of heat, or would raise 14,000 lbs. of water through 1°, which was equivalent to the conversion of 12 lbs. of water at 60° into steam of 120 lbs.

"A comparison was drawn between the recent experiments of Mr. Marshall on the large fire-box engine, and those on the long-boiler engine, made during the gauge inquiry, the results being with the former a consumption of 40 lbs. per mile with an average load of 64 tons, and with the latter a consumption of 27 lbs. per mile with a load of nearly 60 tons. The recorded results of the work of the passenger trains on the Eastern Counties line, for the last half year, showed an average consumption of coke under 18 lbs. per mile run.

"It was contended that hitherto no advantages had resulted from the extension of the fire-box and the reduction of the length of the tubes; still it was possible that this innovation might, by directing attention to the subject, lead to important modifications of the structure of locomotive boilers, which should possess compactness, lightness, power of raising sufficient steam with rapidity for performing the required work, strength to resist the chance of explosions, and a form calculated to diminish the disastrous effects of explosions when they occurred, facility of repair, especially of the fire-box, which was the part most liable to deterioration, being most severely acted on by the fire, and also requiring more support than the tubes, the latter being at the same time cheaper and of thinner metal, while by an extension of their length the diameter of the external shell of the boiler could be diminished; the fire-grate should not be larger than would evaporate the required quantity of water into steam within a given time, with the utmost practical economy of fuel, and if that were accomplished, it was of little importance whether the evaporating heat was communicated through the fire-box or by the tube surface; and that up to the present time the results of the experiments upon the boiler with enlarged fire-box and shortened tubes exhibited rather a retrograde step than an onward progressive movement."

The efficiency of the different parts of the heating surface of the locomotive boiler as evaporators has been found by M. Petiet, of the Northern Railroad of France, who divided a locomotive boiler having tubes 12 ft. 3 in. long into five compartments, to be as follows:*

	First Section. Fire-box + 3 in. of tubes.	Second Section.	Third Section.	Fourth Section.	Fifth Section.
Heating surface in sq. ft.	76.43	179	179	179	179
Water evaporated per square foot per hour, in lbs.:					
With coke	24.5	8.72	4.42	2.52	1.68
With briquettes	36.9	11.44	5.72	3.52	2.31

From this and other experiments, M. Havrez has deduced a law that the quantities of water evaporated by consecutive equal lengths of fire-tubes, commencing from the point where the radiation of the heat from fuel ceases, decrease in geometrical proportion, the distances from this point increasing in arithmetical proportion. T. F. K.

LOCOMOTIVE—TRACTION, ADHESION, AND RESISTANCES. TRACTION.—Under the name of "tractive force" is understood the force which moves the locomotive and train on a road. Some authorities make a distinction between the "tractive force" and the "tractive power," the latter representing the mechanical work, which is the product of the force by the velocity, and can be represented in foot-pounds. The tractive force is the result of the action of steam in the cylinders, and is the same force as that which is transmitted by a belt of the main-shaft pulley of a stationary engine. This can be easily understood if we imagine the pulley to be substituted for the locomotive driving-wheel, and the belt for a rail, the result being here so far different that the driving-wheel (representing the pulley) advances, while the rail (representing the belt) is stationary. If a locomotive be lifted above the track, and belts be attached to its driving-wheels, the force transmitted by them will be the same as the tractive force exerted by the locomotive to pull a train on the track. Devices have been contrived whereby locomotives have been thus used, power being taken directly from the driving-wheels.

The tractive force of a locomotive represents thus the force transmitted from the cylinders to the circumference of the driving-wheels, and is to be distinguished from the force acting at the locomotive draw-bar, which is equal to the first diminished by the force of resistances caused by the movement of the locomotive itself on the track. The tractive force is calculated in the same manner as is the force transmitted to the belt of a stationary engine. It depends upon the steam-pressure on the pistons, the stroke of the pistons, the diameter of the driving-wheels, and the length of the main connecting-rods. The last factor is in practice seldom taken into consideration, being of small importance. The tractive force during each revolution has its maximum and minimum—the first taking place at the time when both crank-pins are on the cylinder side of the axle, and *vice versa*.

The minimum tractive force is calculated by the formula $\frac{d^2 s}{D} P$, where d represents the diameter of the cylinders, s the stroke of the pistons, D the diameter of the driving-wheels, and P the average effective steam-pressure during the whole stroke, in pounds per square inch of the pistons. The

* *Annales du Génie Civil*, August and September, 1874.

maximum tractive force will be obtained by multiplying the result of the above formula by the factor $\left(\sqrt{2} + \frac{r}{l}\right)$, where r represents the length of the crank (one-half the piston stroke), and l the length of the connecting-rod. In practice only the minimum value of the tractive force is calculated. All the factors represented in the above formula, excepting P, which represents the steam-pressure, are constant; and the difficulty is therefore connected only with the calculation of the average effective steam-pressure in the cylinders. This is calculated in the same manner as on stationary engines (see EXPANSION OF STEAM, etc.) with variable cut-off. (See also table in LOCOMOTIVE, PROPORTIONS OF THE.) The point of cut-off should be set at one-third or one-fourth of the stroke, when calculating the size of cylinders for a new locomotive, in order to make the most of the expansion. A shorter admission is not advisable for locomotive engines, it being believed that the differences in strain on the mechanism at the two ends of the stroke are injurious, and that with the link-motion the advantages of expansion would hardly compensate for the losses from the increased compression and the early exhaust.

Compound engines have been applied to locomotives with the object of economizing the steam by a better expansion.

The back piston-pressure in locomotive engines is greater than on other classes of engines. This is partly on account of a higher piston-speed, but in greater degree is owing to the contracted exhaust, by which the draught through the chimney has to be increased. In the following table are given the results of experiments made by Bauschinger to ascertain the influence of the size of the exhaust-nozzle on back pressure.*

Table showing Effect of Size of Exhaust-Nozzle on Back Pressure in Locomotive Cylinders.

Speed in No. of Revolutions per Minute.	Pressure at the Commencement of Exhaust in Lbs. per Square Inch.	Opening of Nozzles in per cent. of the Piston Area.	Back Pressure in Lbs. per Sq. In.	REMARKS.
94	58	9.4	8	Admission, back end = 0.88
84	52	7.8	8	" front " = 0.48
79	58	6.2	8½	
94	55	8	10	
179	22	18	2½	Admission, back end = 0.82
191	22	8.8	8	" front " = 0.41
72	87	18	8½	" back " = 0.51
171	38	10	7	" front " = 0.60
	Back. Front.		Back. Front.	
180	19 24	11.8	½ 2	" back " = 0.14
149	21 27	9.5	8 5	" front " = 0.27
127	88 85	7.6	5 6½	" back " = 0.21
148	89 41	11.8	8½ 1½	" front " = 0.85
92	40 42	11.8	½ 1	
162	14	9.2	4	" back " = 0.17
185	16	8.6	6½	" front " = 0.28
184	18	9.2	4½	" back " = 0.22
164	11	4.4	7	" front " = 0.29
92	50	12.2	8	" back " = 0.58
96	46½	8.8	9	" front " = 0.57

The nearest correct value for P can be obtained only by experiments, from indicator diagrams. From such experiments Welkner † deduced a formula giving an approximate value of the average steam-pressure in the locomotive cylinder, in pounds per square inch, namely: $P = \frac{p}{90}(10\sqrt{a} - 22)$, where p represents the effective steam-pressure in the boiler in pounds per square inch, and a the admission of steam into the cylinders in per cent. of the stroke. Clark gives the following formula: $P = \frac{p}{100}(13.5\sqrt{a} - 28)$, where, however, p is not the boiler but the initial cylinder steam-pressure. All the formulæ for calculating the tractive force give only its approximate value, and there are no means of ascertaining it accurately except by experiment. Usually, that portion of it which is obtained at the locomotive draw-bar is measured by means of a dynamometer.

ADHESION.—In close relation with the tractive force of a locomotive is its adhesion, by which is understood the friction between the rails and the locomotive driving-wheels. It is evident that if there was no friction the wheels would skid, just as a belt would slip on a pulley under the same circumstances. It was not known in the early days of railroad construction that this friction would give sufficient resistance to prevent the wheels from skidding, and geared wheels working in rail-racks were thought to be necessary. The surfaces of the wheels and the rails can be considered as if they were provided with infinitely small teeth, which furnish the resistance that prevents skidding. Upon the nature of these surfaces depends the greater or smaller amount of adhesion. The tractive force, as has been said, represents a force acting on the circumference of the driving-wheels. This force tends to turn the wheels loosely on their axes, without giving them any tendency to advance; but it meets a resistance in the friction which prevents such rotation. Now it is evident that if the tractive force be greater than the friction it will overcome the latter, and the wheels will rotate

* "Indicator-Versuche" in *Civil-Ingenieur*, xiii. Heusinger's "Eisenbahn-Technik," iii.
† "Die Locomotive," Göttingen.

on their axes without advancing. It is thus necessary to limit the tractive force of a locomotive by the amount of the adhesion. The advancing movement of the locomotive can be explained by considering the driving-wheel as a lever whose fulcrum is the point of contact between the wheel and the rail, and on which act two equal forces, representing the steam-pressure in the cylinder; one of them, acting on the crank-pin, is transmitted from the piston, and the other, acting on the axle, is transmitted from the cylinder-head. They act relatively in opposite directions, which are reversed for each half revolution, according as the piston is in its forward or backward stroke. If the crank-pin is above the axle, it acts on the longest lever, and thus counteracts the force acting on the axle, and leaves a balance of force which causes the axle to advance; if the crank-pin is below the axle, the directions of the forces are the reverse, and it is the force of the axle which acts on the longest lever. This counteracts the force of the crank-pin, and a difference is left which causes the axle to advance. This balancing force acting on the axle is in both positions of the crank the same, and equal to the tractive force calculated by the above formula. Its point of application is the centre of the axle, through which only it can be transmitted to the draw-bar; but should the wheel skid, this force immediately disappears from the centre of the axle (which becomes then the fulcrum), and acts on the circumference of the wheel. Adhesion, as preventing skidding and forcing the wheels to advance, is thus of great importance for locomotives. It depends upon the influence of the weather, and varies between the limits of one-third to one-ninth (the coefficients of friction) of the whole pressure of the driving-wheels on the rails. Experiments conducted by various engineers to ascertain the coefficients of friction disagree as to its value. Those made by Messrs. Vuillemin, Gebhard, and Dieudonné,* on the Eastern Railroad of France, gave the following results: In dry weather, $\frac{1}{7.5}, \frac{1}{7.6}, \frac{1}{5}, \frac{1}{6.6}, \frac{1}{8.8}, \frac{1}{6}, \frac{1}{8}, \frac{1}{6.8}, \frac{1}{7.4}, \frac{1}{7}, \frac{1}{8.1}, \frac{1}{8}, \frac{1}{9.5}, \frac{1}{8}, \frac{1}{5.9}, \frac{1}{6.8}, \frac{1}{5.8}, \frac{1}{4.4}, \frac{1}{5.6}, \frac{1}{5.8}, \frac{1}{5}, \frac{1}{5.2}, \frac{1}{6.1}, \frac{1}{7.4}, \frac{1}{6.2}, \frac{1}{7.7}, \frac{1}{6.1}, \frac{1}{5.7}, \frac{1}{6.1}, \frac{1}{6.4}, \frac{1}{6.1}, \frac{1}{6.3}, \frac{1}{5.2}$; in somewhat wet weather, $\frac{1}{7.6}, \frac{1}{7.2}$; in wet weather, $\frac{1}{12.8}, \frac{1}{6.1}$; in light rain, $\frac{1}{11.1}$; in rain, $\frac{1}{8.4}, \frac{1}{9.2}, \frac{1}{8.8}, \frac{1}{11}, \frac{1}{8}, \frac{1}{5}, \frac{1}{4.9}, \frac{1}{6.5}$; in rain and fog, $\frac{1}{8.7}, \frac{1}{7.6}, \frac{1}{6.9}$; in heavy rain, $\frac{1}{6.3}, \frac{1}{6.3}$. These experiments, as also others made by Wood and by Séguin, agree that the best adhesion is obtained when the rails are dry or perfectly wet. Under very bad circumstances, as for instance on greasy rails, the coefficient of friction will sink as low as $\frac{1}{25}$. The speed probably also exerts an influence on the adhesion. Experiments made by Poirée † have shown that the friction between wheels and rails diminishes when the speed increases. As these experiments, however, were made with a car so arranged that the wheels would slide, no deduction can be made from which the adhesion can be safely ascertained. The amount of adhesion deduced from actual performances of locomotives, especially on steep gradients, can be very approximately obtained, and gives better results. On the North London Railway a locomotive weighing 45 tons, of which 32 tons constituted the adhesive weight, has hauled in favorable weather a train weighing 359 tons (locomotive included), on a grade of 0.022. The resistance of gravitation alone, amounting to 7.893 tons, is just $\frac{1}{4.05}$ of the adhesive load.‡ Mr. Latrobe states § that during the construction of the Kingwood tunnel, on the Baltimore and Ohio Railroad, one of the Ross Winans "camel engines" with eight wheels, coupled, weighing 56,000 lbs., all on drivers, hauled a total gross weight of 120,000 lbs. up a grade of 528 ft. to a mile, or 1 in 10, combined with a curve of 300 ft. radius. The resistance of gravitation to be overcome amounted to 12,000 lbs., and the remaining resistances, estimated by Mr. Latrobe at 1,828 lbs., give a total of 13,828 lbs. (which figure, if taken somewhat too large, would cause a comparatively small error, the resistance of gravitation being accurate, and so much in excess of the remaining portion). The tractive force, therefore, divided by the weight of the locomotive, will give $\frac{56,000}{13,828} = 4.05$, or an adhesion of $\frac{1}{4.05}$. Mr. Chanute states‖ that the locomotives on the Erie Railway work regularly up to an adhesion of from $\frac{1}{5}$ to $\frac{1}{4.5}$, with occasional performances much in excess. In practice a coefficient of friction found by experience to be small enough not to admit of skidding, excepting perhaps under very unfavorable circumstances, is usually taken by French engineers at $\frac{1}{7}$,¶ by German engineers at $\frac{1}{6.6}$** (this being the proportion of the tractive force, calculated for an average steam-pressure in the cylinders equal to 50 per cent. of the boiler-pressure, to the adhesive load), and by American engineers at $\frac{1}{5}$.

The capacity of a locomotive being actually limited by the adhesion, the increase of the latter from

* "De la Résistance des Trains," etc., Paris, 1868.

† *Annales des Mines*, 5th series, xiii., 1858.

‡ Couche.

§ *Railroad Gazette*, vi., 471.

‖ "Transactions of the American Society of Civil Engineers," vii., 215.

¶ Couche.

** Heusinger's "Eisenbahn-Technik."

the beginning occupied the minds of engineers. The first means of increasing it is by coupling the axles together, until the whole weight of the locomotive can be utilized for adhesion. If, however, all axles of the locomotive are coupled, they present a long rigid wheel-base, which affects easy movement on curves, and causes cutting of wheel-flanges. To provide against this, the axles are placed as close as the diameter of the wheels will allow. Various devices have been tried with the object of increasing the adhesion and thus the power of locomotives, by increasing the weight on the drivers, as in tank locomotives, where the supply of water and fuel is placed on the engine, or by multiplying the number of driving-axles without presenting a long rigid wheel-base. The Fairlie, Masson, Haswell, Engerth, and other locomotives (see LOCOMOTIVES, CLASSIFICATION AND FORMS OF), have been designed for this object. As the maximum force of the locomotive is required on steep grades only, which usually extend over but a short distance of the road, efforts have been made to provide only for an increase of the weight on drivers when this may be required. Paulus,* in 1855, employed a device by which he could throw at will a portion of the weight of the tender on the locomotive, increasing the adhesion from 25 to 30 per cent. This, however, was soon abandoned. Sturrock attached auxiliary cylinders to the tender, which were employed as helpers on steep grades. Sand is universally used as means of increasing the adhesion by throwing it on the rails when required. This is usually performed by moving a valve by hand, but attempts have been made to supply a continual discharge regulated by mechanism, in case it is necessary to continue such discharge for a long time. Riggenbach employed apparatus of this kind in tunnels; but owing to the complication of mechanism, it was abandoned. Magnetism has also been tried to increase the adhesion. Experiments were made in Paris which did not prove at all successful; but a better success was obtained on the New Jersey Central Railroad, where the adhesion was thus increased to 40 per cent. The idea has not yet been practically utilized. Sellers in Cincinnati, in 1847, was the first to employ a third rail acted on by two horizontal wheels, pressing against it, and thus increasing the adhesion. Brown of Winterthur, in 1878, suspended a platform between two locomotives, which, together with the weight of its cargo, increases the load on the drivers.† Locomotives for very steep grades have to be provided with geared wheels which work in rail-racks. (See RAILROADS, MOUNTAIN.)

RESISTANCES.—The resistances which the locomotive has to overcome can be divided into the resistance caused by the movement of the locomotive alone, and that caused by the movement of the train, consisting of the tender and cars. The first can be subdivided into (1) resistance due to the action of steam itself, as back pressure on the pistons (which, however, is usually taken into account when calculating the tractive force); (2) resistance caused by the moving mechanism of the engine, creating friction and internal disturbing forces; and (3) resistance caused by the movement of the locomotive as a carriage on the track, which last is the same as train resistance. Train resistances are usually the only ones calculated, and are given in pounds of the tractive force per ton of the train hauled. For each ton weight of the locomotive 50 per cent. is usually added to the per ton resistance of the train.

Pambour has determined the resistance of the locomotive itself in the following manner: He allowed the steam-pressure of the locomotive to sink low enough to be hardly sufficient to move the locomotive on the track. From this he deduced a formula showing the resistance of the locomotive to equal $7q + 48$ lbs., or $7q + 59$ lbs. per ton, where q is the weight of locomotive, including the tender, in English tons; the first formula is for locomotives with uncoupled axles, and the second for locomotives with coupled axles. For the increased amount of friction of the locomotive mechanism caused by the exertion of the tractive force, he adds one-seventh of the total resistance of the train, excluding locomotive and tender.

Train resistances are made up of the following factors:

1. Journal-friction, which depends upon the diameter of the journals, the load carried on them, the coefficient of friction, and the diameter of the wheels. It can be expressed by the following formula: $R = f'\,Q'\,\frac{d}{D}$; where R is the resistance acting on the circumference of the wheel, f' the coefficient of the journal-friction, Q' the load on the journals, d the diameter of the journals, and D the diameter of the wheels. The coefficient of friction is the only quantity unknown, which has to be ascertained by experiments. It depends largely upon the quality of the lubricating matter, and is said to be independent of the amount of bearing surfaces and the speed, which opinion is, however, to some extent disputed. (See FRICTION and LUBRICANTS.) Experiments made in 1862 in railroad shops in Hanover gave a friction coefficient at 0.01 on car-axles provided with composition bearings and lubricated with oil, which axles were taken out for that purpose from under cars in actual service. Vuillemin, Dieudonné, and Guebhard have found this coefficient to be 0.018, by deducting from the total train resistance 0.001 of the total weight of the train, as the allowance for the rolling friction; the train, moving at a very slow speed, was considered free from the resistance of the air. The American 20-ton freight car, having 3¾-in. journals and 33-in. wheels (the weight of wheels and axles taken at 3 tons), would give, with a coefficient of friction of 0.01, a resistance by journal-friction of 1.92 lb. per ton, and with a coefficient of 0.018 a resistance of 3.45 lbs. per ton of the total weight, which latter is nearer to the truth.

2. Rolling friction is represented in the mechanical work expended in the wear of the rails and the wheel-treads. It depends upon the pressure of the wheels on the rails, the diameter of the wheels, the hardness of material of which the wheels and rails are composed, and the surfaces of contact of the two. Pambour expressed it by the formula $R = \frac{f''\,2}{D}\,Q$, where R is the resistance of the rolling friction at the circumference of the wheel, f'' the coefficient of the rolling friction, Q

* *Organ für Eisenbahnwesen*, 1857. † *Railroad Gazette*, 1879.

the weight or pressure on the rails, D the diameter of the wheel, and f'' is an expression of the unit of length. If D is expressed in inches, f'' has been found by Pambour, from experiments, to be 0.02. For 33-in. wheels, the resistance due to rolling friction would thus be equal to 0.0012 of the load, amounting to 2.4 lbs. per ton.

Journal and rolling frictions are, if taken together, called the wheel-friction, and for this 6 lbs. is ordinarily allowed in calculations.

3. The resistance caused by passing over the rail-joints, which causes vertical and horizontal movements to the car, is difficult to determine. It is believed to be proportional to the weight and the speed. Its total amount decreases as the length of the rail increases. It can be expressed by the formula $R = a\ Q\ W$, where R is the resistance caused by passing the rail-joints, Q is the weight of the train, W the speed, and a the coefficient to be determined by experiment. (The length of rail is left out in the formula, as it is generally the same on all roads.) The influence upon this resistance exercised by a more or less careful method of laying the rails on the road has been shown in experiments made for this purpose by Vuillemin, Dieudonné, and Guebhard, who found an increase of the tractive force amounting to 19 per cent. on a road with carefully-laid rails, over that of a road with badly-laid rails, at the speed of 46.5 miles per hour.

4. The resistance of gravitation caused by the moving of a train up an incline, usually called grade, is proportionate to the amount of grade, which is the amount of the ascent in a certain distance of the road. This amount is usually given in feet per mile, or in per cent. of the length of the incline, or is reduced to the simplest fraction giving the length of the incline to a unit of the ascent. For example, if a grade is said to be 528 ft. to a mile (5,280 ft.), the second expression would be 0.10, or 10 per cent., and the third $\frac{1}{10}$, which would mean that there is 1 ft. of rise in 10 ft. of the length of the incline. This last quantity is called the ascent, and represents the sine of the angle which the incline forms with the horizontal line. It being known from the theory of mechanics that the force required to move a body up an incline is proportionate to its weight and the sine of the angle, we have for the resistance of gravitation alone the formula $R = Q\,i$, where R is the resistance due to gravitation, Q the weight, and i the ascent. This is the only train resistance which can be determined with mathematical exactness.

The three foregoing resistances are slightly diminished on a grade, as the component of the force of gravitation which acts perpendicularly to the incline is proportionate to the cosine of the angle, which is less than 1; but as this angle is very small, its cosine is almost equal to 1, and causes a difference not worth considering.

5. The resistance caused by the movement on curves can be calculated only with very complicated formulæ, without any certainty of exactness. The results of experiments are therefore the only data to be depended upon. For a single four-wheeled car, Redtenbacher gives the formula

$$R = f\,Q\,\frac{\frac{b}{2} + \frac{l}{2}}{r};$$

where f is the coefficient of the sliding friction, b the gauge of the road, l the distance between wheel-centres, Q the weight of the car, and r the curve radius of the centre-line of the track. This formula cannot be applied to cars composing a train.

Von Weber has made experiments to ascertain resistances on curves, and has given in the following table a comparison of his results with those obtained by Polonceau, by English engineers, and by calculation from the formulæ of Perdonnet, Schmidtl, and Redtenbacher. The cars taken are four-wheeled, with a distance between wheel-centres of 12 ft. and 11 ft. 8 in. The values given in the table represent the total train resistance on the curves, the resistance on a straight level line being taken as a unit; in other words, they are the factors by which the resistance on a straight level track has to be multiplied to give the total resistance on the corresponding curve.

RADIUS OF THE CURVE.	Polonceau.	English Engineers.	Perdonnet.	Schmidtl.	Redtenbacher.	Von Weber.
1,858 ft.	1.756	1.41	1.429	1.422	1.749	1.40
1,486 "	1.941	1.50	1.588	1.552	1.936	2.03
1,114 "	2.144	1.68	1.716	1.691	2.247	2.48
929 "	2.258	1.80	1.858	1.788	2.498	....
743 "	2.881	2.09	2.077	1.984	2.872	3.02
557 "	2.491	2.35	2.482	2.292	3.494	4.27
371 "	2.668	3.00	3.153	3.132	4.744	4.83
334 "	2.718	3.27	3.863	3.988	5.988	8.85
Straight track.	1	1	1	1	1	1

The different results contained in this table indicate the difficulties connected with ascertaining the curve resistance.

Experiments made by Mr. Benjamin H. Latrobe in 1844, on the Baltimore and Ohio Railroad,† with the object of ascertaining the comparative merits of four-, six-, and eight-wheeled cars, gave the following average results:

CARS.	Traction in Lbs. per Ton of 2,240 Lbs.	
Four-wheeled car.	4.94 on straight line.	8.70 on curve 400 ft. radius.
Six- " "	7.55 " " "	14.99 " " " "
Eight- " "	7.49	15.98

* Heusinger's "Locomotivbau."

† *Railroad Gazette*, viii., 34.

The average increase of resistance due to the curve of 400 ft. radius, computed from these experiments, gives 6.4 lbs. per ton. Mr. S. Whinery, in a paper read before the American Society of Civil Engineers,* divides the resistances of curves into their several elements, giving formulæ for calculating each of them. In the discussion of the paper, Mr. O. Chanute states that the formulæ given by the author agree with experiments made on the 6-foot gauge Erie Railway by Zerah Colburn in 1854, who found that the resistance due to curves amounts to half a pound per ton per degree.† He further states that experiments made on the Metropolitan Elevated Railroad in New York, in 1878, with two trains, each of four cars weighing 40 tons, on a gauge of 4 ft. 8½ in., and on a curve of 90 ft. radius (63° 40′), one of which trains had wheels fixed on their axles, while the other was provided with wheels loose on their axles, gave the following result:

	Rigid Wheels.	Loose Wheels.
Traction on curve, lbs.	1700	1300
Traction on straight line, lbs.	600	450
Increased resistance per ton	27.50	21.25
Resistance per ton per degree	0.4319	0.3337

6. Resistance of the air is a very important component of the total resistance for fast trains, as it increases with the square of the velocity. It is composed of the resistance caused by the displacement of the air by the train, and of the resistance caused by the wind. If the wind blows at an angle to the direction in which the train is moving, it causes, besides the friction on the side of the train, a partial lateral movement of the train on the track, causing on conical wheels a resistance due to the wheels running on different diameters; and it may cause also flange-friction. To determine the resistance of the air which acts in the direction of the train, the following formula is used: $R' = a' A (v \pm u \cos. b)^2$, where R' is the resistance, A the surface of the train presenting the face against the air in the direction of motion, v speed of the train, u velocity of the wind, b angle inclosed between the direction of the wind and that of the train, and a' a factor to be determined by experiment. The plus or minus sign is taken with u according to the direction of the wind, whether with or against the train. Pambour's formula for calculating the resistance of the air, deduced from his experiments, is: $R = 0.002687\ A\ v^2$, where R is the resistance, A the surface (by him taken as being equal to 70 sq. ft. plus 10 sq. ft. multiplied by the number of vehicles in the train, including the locomotive and tender), and v the speed in miles per hour.

To calculate the total train resistance on a level straight road, many formulæ are given, some of which are as follows:

Clark's formula: $R = \left(8 + \frac{v^2}{171}\right) Q$; where R is the total train resistance in pounds, v speed of the train in miles per hour, Q total weight of the train in English tons.

Pambour's formula: $R = \left(1 + \frac{1}{7}\right)(6\ Q + 0.002687\ A\ v^2) + R'$; where R is the total train resistance, Q the weight of the train, exclusive of the locomotive, in English tons, v the speed of the train in miles per hour, A the surface in square feet (by him taken to be equal to 70 sq. ft. plus 10 sq. ft. multiplied by the number of vehicles in the train), and R' the locomotive's own resistance. The signification of the factor $\frac{1}{7}$ has been explained when speaking of the locomotive's own resistance.

T. F. K.

LOCOMOTIVES, CLASSIFICATION AND FORMS OF. Locomotives can be variously classified in regard to their construction. They may have inside or outside frames, inside or outside cylinders. They may be divided according to the number and kind of wheels, and in regard to whether the supply of fuel and water is carried on separate tenders or on the locomotives themselves, wholly or partly, forming the separate classes of locomotives with tenders and "tank locomotives." Locomotives may also be classified with reference to the various kinds of service which they perform, as passenger, freight, and switching locomotives. This classification also embraces mountain, mining, suburban, street-car, and factory locomotives. Considered with regard to the gauge of the road on which they run, they are denominated standard-, broad-, and narrow-gauge locomotives. There are various other kinds of locomotives which must be separated from those already enumerated, on account of their peculiar construction, as for instance double-cylinder or double-piston locomotives; or on account of the motive force being differently applied, as for instance fireless (hot-water) and compressed-air locomotives. Locomotives built and used in various countries differ from each other so materially that they could be divided into American, English, French, and German locomotives; the principal characteristic difference, however, existing only between American and European locomotives.

Passenger Locomotives.—The principal requirement of this kind of locomotives is speed with a comparatively small tractive force; hence their characteristic features are: 1st, large diameter of driving-wheels with short piston-stroke, the object being to diminish the piston-speed and thus the internal disturbing forces, which in this case would be not only destructive but also dangerous; 2d, large capacity of boiler in proportion to the tractive force. These characteristics are carried to the extreme on the passenger "express locomotives," a class which in America actually does not exist, and in Europe is disappearing. Regarding the speed of trains, there is a distinction to be made

* "Transactions," vol. vii., page 79.

† The radius in feet of a certain degree of curve can be found by dividing 5,730 (the radius of 1° curve) by the degree of the curve under consideration.

between their actual speed—that is, the distance run in a unit of time between stopping points—and the time of running between two distant stations of the road, as for instance between New York and Philadelphia. An ordinary passenger train usually attains just as high an actual speed as an express train; yet on account of frequent stops it loses so much of its time as to make a large difference in the total run between the end stations. By an examination of the railroad time-tables, it will be even found that when an allowance of 2½ minutes is given for a stop—which is a very small limit for checking speed, disembarking and taking on passengers, and bringing the train back again into its former velocity—an accommodation train has often to run at a higher actual speed than an express train, to be on time. With the increased traffic of the present day, no road can afford to run very slow trains, nor are the express trains as light now as they used to be. The necessity has thus arisen for more powerful express locomotives, and the original express locomotive, with but one driving-axle, has been replaced by one with two coupled axles. The ordinary passenger locomotives, on the other hand, came to require some of the qualities of the express locomotives, so that the differences between the two types as formerly recognized are, as we have stated, either obsolete or obsolescent. The highest locomotive speed thus far attained has been made in England, where on the Great Northern Railway, in trials made with some new locomotives, a velocity of 74 miles an hour was accomplished by trains of 16 cars.* The fastest English and American regular express trains run at from about 45 to 50 miles an hour.

The question of the safety of running at high speeds with various kinds of locomotives has been investigated by a commission appointed by the Prussian Ministry of Commerce in 1873. It was decided that the maximum speed for express locomotives should be at the rate of a German mile in 6 minutes (46.5 English miles per hour), and that the maximum safe speed for various locomotives depends upon the distribution of the load on the axles, upon the wheel-base, upon the diameter of the driving-wheels, and upon the counterbalancing.† Regarding the wheel-base, there are no passenger locomotives in Europe, excepting those with a four-wheeled truck in the front, which can equal the eight-wheeled standard American locomotive, and the result in the latter case is a greater steadiness and consequently an increased limit of the maximum speed, other conditions being equal.

American passenger locomotives, as built by the Grant, Baldwin, and Hinkley Locomotive Works, are illustrated in Figs. 2869, 2870, and 2871. There is no material difference in the designs, excepting in point of dimensions.

European passenger locomotives have either one, two, or (rarely) three coupled axles. Fig. 2880 represents an English type of express locomotive. The disadvantage of this form is that it raises the boiler and consequently the centre of gravity of the locomotive too high, on account of the large driving-wheels. Crampton has improved this design by placing his driving-axle behind the fire-box, as shown in Fig. 2881, which style of locomotive is generally known by his name. Fig. 2882 represents the other style of European passenger locomotive. This is more powerful than the express locomotive, and is used for heavier express or accommodation trains. This style of locomotive is sometimes called "mixed," the name having originated from the fact that it was formerly used for hauling trains composed of both passenger and freight cars. Some passenger locomotives are built in Europe on the American plan, with four driving-wheels and a four-wheeled truck in front; but generally they are six-wheeled, the wheel-base being rigid.

FREIGHT LOCOMOTIVES.—The chief requirement of this class of locomotives is great power with comparatively low speed. Their distinguishing characteristic is great adhesive weight, large cylinders, and small driving-wheels. There are four principal types of freight locomotives used in America.

The standard American locomotive is the same as that used for passenger traffic, but with smaller driving-wheels and larger cylinders.

The Mogul locomotive, with six wheels coupled and a two-wheel truck in front, is shown in Fig. 2872.

The ten-wheeled locomotive, Fig. 2873, has six wheels coupled and a four-wheel truck in front.

The Consolidation locomotive, Fig. 2874, has four wheels coupled and a two-wheel truck in front.

In Europe, the whole weight of the freight locomotive is utilized for adhesion. The axles are placed between the fire-box and the cylinders, thus leaving great overhanging weights, which with the short wheel-base makes these locomotives very unsteady in motion. Fig. 2883 represents a six-wheeled, and Fig. 2884 an eight-wheeled coupled European freight locomotive.

TANK LOCOMOTIVES are those which carry their own supply of water and fuel, or which are permanently connected with their tenders. The object of this arrangement is to increase their adhesive weight, and thus their tractive force. They are mostly used in mountainous countries and on narrow-gauge railroads; also for switching purposes, and on metropolitan or suburban railroads. An example of this form of locomotive is shown in Fig. 2875. It has its tank placed on the locomotive-frame, which extends beyond the fire-box. The driving-wheels are placed under the boiler, and the truck under the tender, by which arrangement the whole weight of the locomotive is utilized for adhesion, while a long and flexible wheel-base is preserved. If intended to travel but in one direction, this locomotive is arranged to run with the tender in front. It is used for rapid-transit purposes on the elevated and suburban railroads, and also on narrow-gauge routes.

Fig. 2876 is a *double-ender tank locomotive*, this name indicating that it can run with either end in front. It is of similar design to the locomotive just described, excepting that it has a two-wheel truck in front, which carries a portion of the weight of the locomotive.

Fig. 2885 represents a *Belgian tank locomotive* with water-tanks placed on both sides of the boiler. To admit of its running in curves, the extreme axles are allowed to move laterally in their guards.

There are also tank locomotives which have their tanks placed on the top of the boiler; these are called *saddle-tank locomotives*.

* Heusinger's "Locomotivbau," p. 872. † Ibid., p. 873.

Fig. 2886 represents a tank locomotive built on what is known as the *Engerth system*. Its tender is placed on a separate frame, so arranged that it can be pushed under the boiler, the fire-box of which comes between the tender-axles. The tender-frame is pivoted to the engine-frame by a centre-pin, admitting thus of an easy motion on curves. This style of locomotive is disappearing on account of its repairs being too costly.

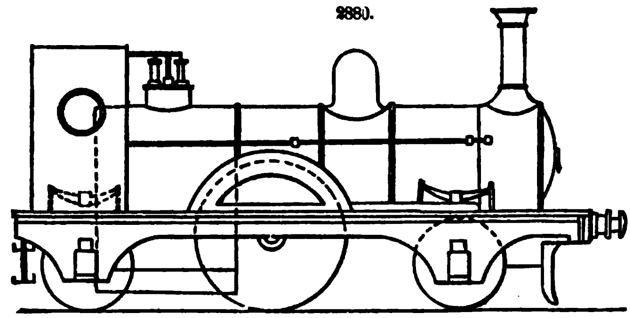
Fig. 2877 represents a double-truck tank locomotive, known in America as *Mason's locomotive*, which, similarly to the Fairlie locomotive, is supported on two trucks—one carrying the boiler on a centre-pin, and having the cylinders attached to the truck-frame, and the other supporting the tender, which is placed on the same frame with the boiler.

Fig. 2887 represents a small tank locomotive designed by Mr. Brown of Winterthur, Switzerland. Its peculiarity is, that the movement of the pistons is transmitted to the driving-wheels by means of rockers, fastened on a rocking-shaft. This

design admits of very small driving-wheels with a convenient position of the cylinders. It dispenses with the counterbalance weights, as the reciprocating parts are balanced by the connecting-rods. The tank is here placed under the boiler, the frame-plates forming its sides.

Switching Locomotives have the same characteristics as freight locomotives. They require even a proportionately greater adhesive weight, as their duty is to shift cars and trains in the depot yards, thus constantly reversing their motion, while the rails are, in such places, often rendered slippery by grease from the axle-boxes. They are either four- or six-wheel coupled, and usually of the tank locomotive pattern. Fig. 2878 represents a four-wheel switching locomotive with a separate tender.

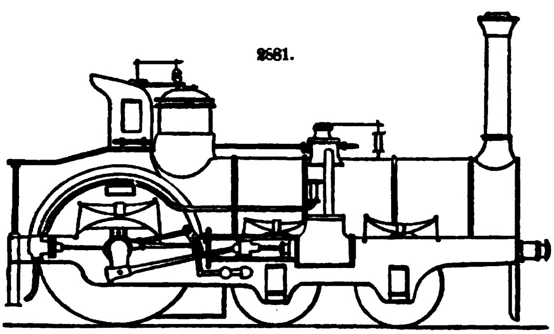
2880.



Other Styles of Locomotives.—Fig. 2879 represents a double-end locomotive for passenger or freight traffic. By this arrangement about four-fifths of the whole weight can be placed on the drivers. This style of locomotive is used on the Metropolitan Elevated Railroad in New York.

Fink's locomotive, Fig. 2888, has been designed for mountain service. It has 10 wheels coupled and so arranged as to run in curves of 275 ft. radius. The three first axles are guided by one frame, and the two hind axles by another frame; the frames are coupled by a pivot-bolt in front of the fire-box, in the same manner as on Engerth's tank locomotives above described. The third is the main driving-axle, and is coupled with parallel rods to the two front axles in the usual manner. The two hind axles are also coupled with each other. The frames being outside, all axles are provided with outside cranks. To transmit the power from the main axle to the hind axles, an intermediate shaft and radiating parallel motion have been devised. This shaft is carried by and above the first of the hind axles, on spherical bearings, and is kept at a constant distance from the main axles by means of rods provided also with spherical bearings. By this contrivance the axles of the front and rear frames may adapt themselves to the varying angularity on curves, without producing the slightest change in the distances of the bearings of the intermediate shaft, and of axles with which they are jointed, admitting thus of coupling the cranks of the intermediate shaft with the cranks of the main and the first hind axles.

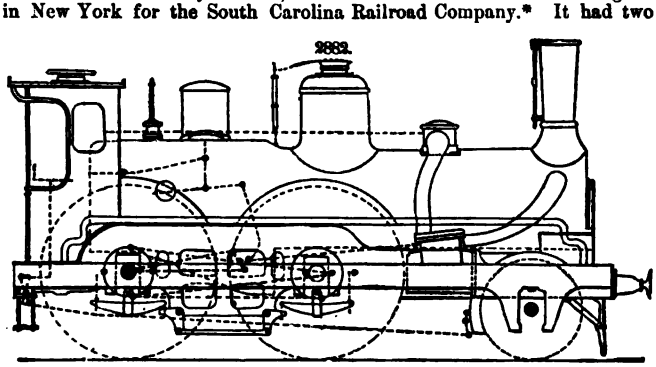
2881.



Four-Cylinder Locomotives.—The first attempts to unite two locomotives in one, thus doubling the power, were made in the United States as early as 1831, when a locomotive of this form designed by Horatio Allen was built in New York for the South Carolina Railroad Company.* It had two boilers with a common fire-box in the centre, and was supported on two bogies. Each bogie had but one cylinder, placed in the smoke-box, and the connections were made by means of ball-joints.

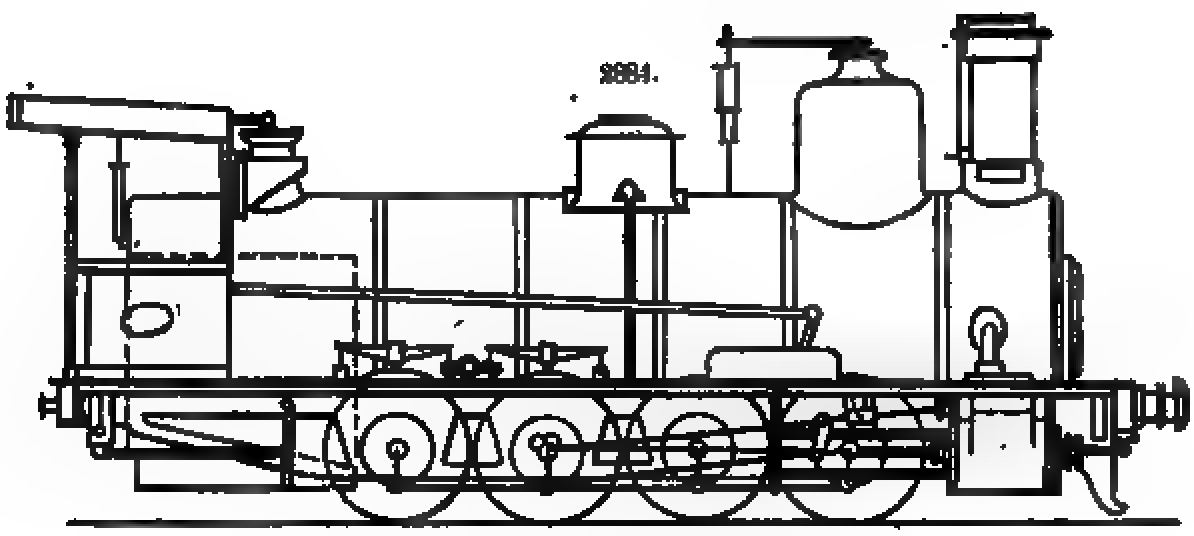
There are two systems of this kind of locomotives, generally known as *Fairlie's* and *Meyer's* systems. The first is represented in Fig. 2889. It consists of a double boiler, with a fire-box placed in the centre, which is divided into two parts by a water space. The whole is supported on two centre-pin trucks, each of which is provided with a pair of cylinders. The steam is carried to the cylinders through a pipe, which connects to the boiler steam-pipe at the centre of the truck. The Fairlie locomotives, although at first thought

2882.

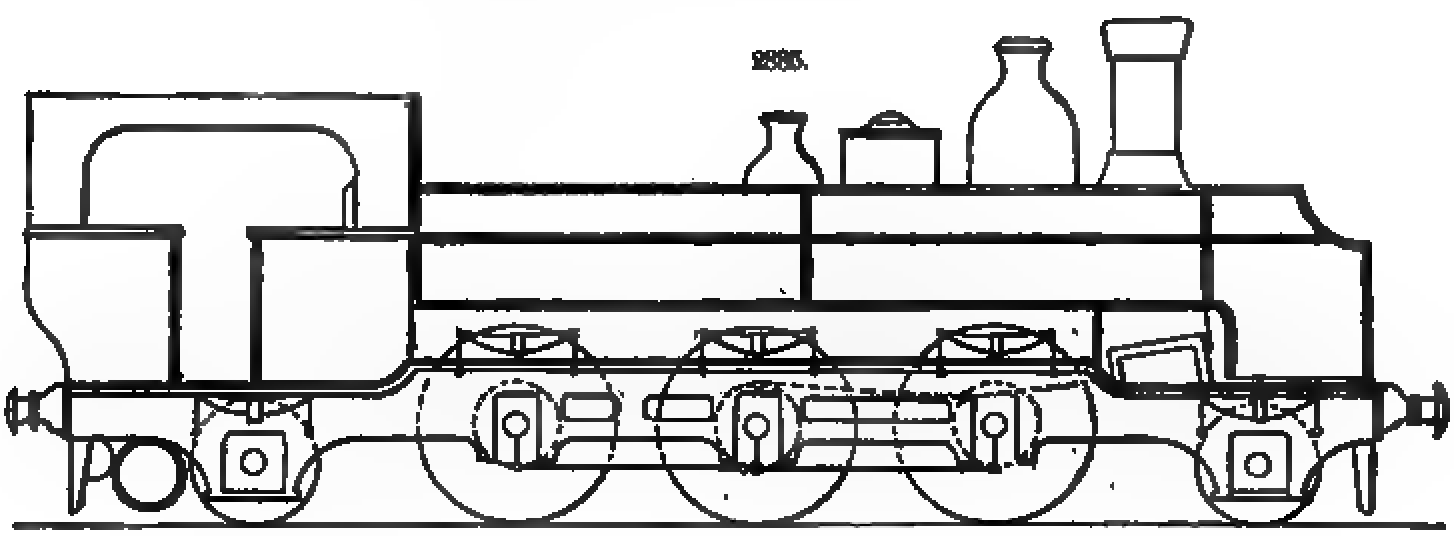


* *Railroad Gazette*, ii., p. 529.

2884.



2885.



to make an epoch in locomotive construction, are not so successful as to guarantee their permanence. Meyer's system differs from the other principally by having a single boiler, and the four cylinders placed toward the centre of the locomotive. Only two of these have been built, both in Belgium.

Four-cylinder locomotives have also been designed by Petiet for the Northern Railroad of France.

M. Beugniot has designed a locomotive for an Italian mountain railroad, which is known under his name. Its peculiarities consist in an arrangement by which the axles move laterally on the track, remaining parallel to each other. Four of the five axles are coupled, and the fifth, which carries only a small portion of the locomotive weight, constitutes the front axle of the tender. Each axle has two inside and two outside journals, the first carrying about three-fourths of the whole weight.

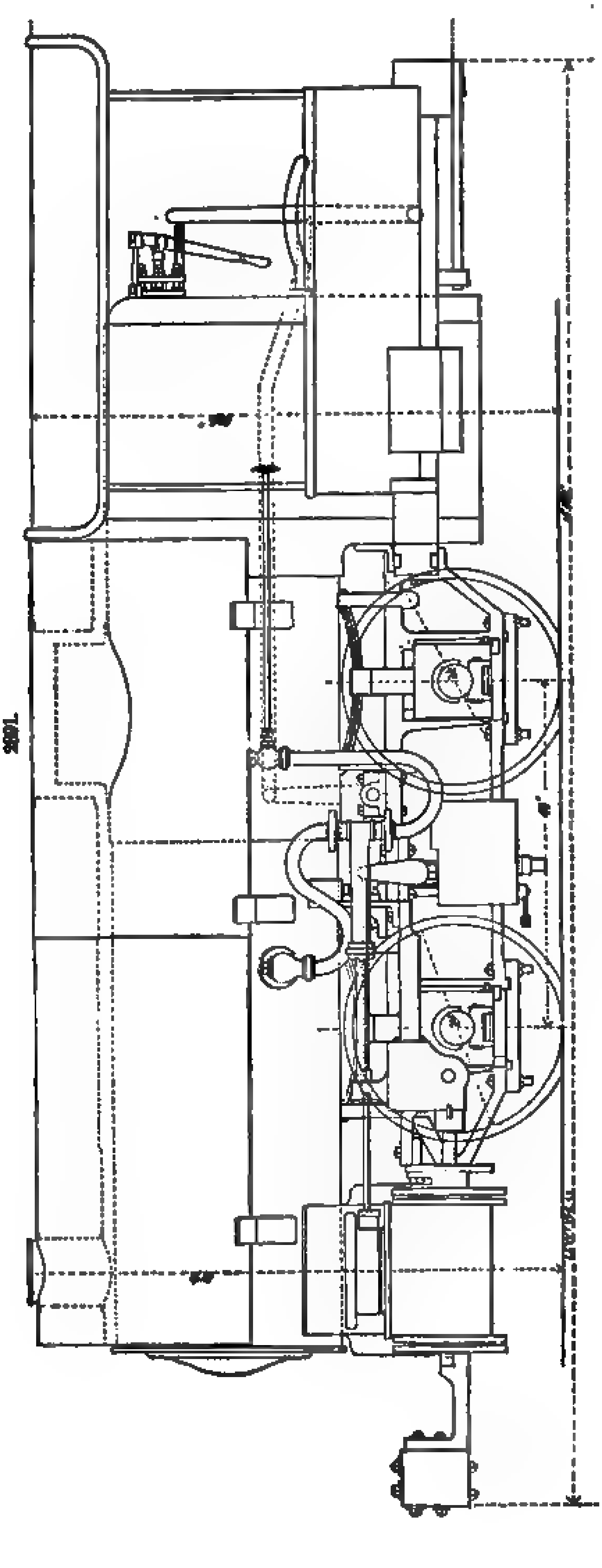
The axle-boxes of the inside journals are provided with vertical pins, above and below, by means of which each two boxes on the neighboring axles, on the same side, are connected with movable frames. The outside journals support a regular locomotive frame, which carry the cylinders. The cross-heads are placed at the reversed ends of the cylinders from their customary position, and each has a pair of connecting-rods, acting on four cranks, of which two are inside and two outside of the main driving-axle.

Locomotives with tenders as helpers have been built in Belgium from designs of Maurice Urban. The tender is provided with two cylinders, which are supplied with steam from the locomotive boiler, and act on the coupled wheels of the tender.

Locomotives for very steep grades, up to 25 in 100, have been provided with a special mechanism to increase their adhesion. Sellers in Cincinnati and Fell on Mont Cenis have applied a pair of horizontal rollers acting on a third rail, placed between the two outside rails. Against this inner rail the rollers are pressed, so increasing the adhesion.

Geared locomotives, working in a rail-rack, have found quite a large application in mountain railroads. Fig. 2890 represents Riggenbach's geared locomotive. The main shaft has two pinions, one to revolve the geared wheel that works in the rack, the other to revolve a second shaft which by means of a crank is coupled to outside wheels, which run on the ordinary rails. The locomotive is propelled either by the geared wheel or by the adhesion of the drivers, and the change from one action to the other is accomplished by moving the pinions laterally on the main shaft, if need be, when the locomotive is in motion.

Double-Piston and Double-Cylinder Locomotives.—A double-piston locomotive has been built in England, from the design of Bodmer, with the object of producing an engine free from internal disturbing forces, and thus capable of the highest speed with perfect safety. Each cylinder is provided with two pistons, their rods projecting at the opposite ends of the cylinders, and acting on



Dimensions, Weights, etc., of American Locomotives, illustrated in Figs. 2869 to 2879.

DETAILS.	Passenger Locomotive, Grant Locomotive Works, Fig. 2869.	Passenger Locomotive, Baldwin Locomotive Works, Fig. 2870.	Passenger Locomotive, Hinkley Locomotive Works, Fig. 2871.	Mogul Freight Locomotive, Baldwin Locomotive Works, Fig. 2872.	Ten-Wheeled Freight Locomotive, Baldwin Locomotive Works, Fig. 2873.	Consolidation Freight Locomotive, Danforth Locomotive Works, Fig. 2874.	Forney's Tank Locomotive, Fig. 2875.	Double-End Tank Locomotive, Rogers Locomotive Works, Fig. 2876.	Double-Truck Freight-Tank Locomotive, Mason Locomotive Works, Fig. 2877.	Four-Wheeled Switching Locomotive, Hinkley Locomotive Works, Fig. 2878.	Double-End Locomotive, Grant Locomotive Works, Fig. 2879
Gauge of road, ft. and in.	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½	4 8½
Number of driving-wheels	4	4	4	6	6	8	4	4	6	4	4
Number of front truck-wheels	4	4	4	2	4	2	4	2	6	None.	2
Number of back truck-wheels	None.	None.	None.	None.	None.	None.	None.	4	6	None.	2
Total wheel base, ft. and in.	21 9	21 9	21 4½	22 9	23 6	20 2	20 9	25 8½	31	6 9	19 9
Distance between front and back driving-wheels, ft. and in.	8 0	8 0	7 6	8 0	7 4	15 7	6 8	6 6	8	6 9	7 6
Total weight of locomotive in working order, lbs.	63,000	65,000	68,000	77,000	78,000	96,550	60,000	75,000	......	48,000	52,000
Total weight on driving-wheels, lbs.	42,000	42,000	41,000	66,000	58,000	84,480	44,000	40,000	66,000	48,000	42,000
Diameter of driving-wheels, in.	61	60½	65	52	51	50	50	42½	43	56	56
Diameter of truck-wheels, in.	29	28	30	30	26	31	26	30 and 26	30	None.	28
Diameter of cylinders, in.	16	16	16	18	18	20	14	15	16	15	14
Stroke of cylinders, in.	24	24	24	24	24	24	20	22	24	22	22
Outside diameter of smallest boiler ring, in.	48	48	46	50	50	50	46	45½	48	44½	42
Length of grate, in.	61	65	60	66	61	120	54	60	66	44	78
Width of grate, in.	34	34½	36	34½	35	34½	36½	34	48½	36	34
Number of tubes	140	144	150	161	152	165	139	180	154	191	124
Diameter of tubes, in.	2	2	2	2	2	2¼	2	2	2	2	2
Length of tubes, ft. and in.	11	10 11	11	11 8	12 9	13 1½	10 7½	8 10½	11 6	10 6	7 10
Square feet of grate surface	14	15.5	15	16	14.87	29	14	11 84	22.17	11	16.5
Square feet of heating surface in fire-box	98	100.6	100	102 7	94	139	78	68	126	71	80.3
Square feet of heating surface in tubes	805	825.4	755	949	1,014	1,370	734	711	927	590	468.5
Total feet of heating surface	903	926	855	1,051	1,108	1,509	812	779	1,053	651	549.8
Ratio { Total heating surface to fire-box heating surface	9 2	9.1	8 5	10.2	11 7	10 8	10.4	9 6	8.3	9.1	6 7
Ratio { Heating surface to grate-area	64 5	59.7	57.0	65.7	77 1	52.0	58.0	66.3	47.4	59.1	33.9
Kind of coal used	Bitum.	Bitum.	Bitum.	Bitum.	Bitum.	Anth.	Bitum.	Bitum.	Bitum.	Bitum.	Anth.
Exhaust-nozzle—single or double	Double.	Double.	Double.	Double.	Double.	Double.	Double.	Double.	Single.	Double.	Double.
Diameter of nozzle, in.	3½ to 3¾	3¼ to 3½	3	3 to 3¼	3 to 3¼	3¼	3½	2⅝ to 2¾	Variable.	2¾	2½ to 2¾
Length of steam-port, in.	14	15	14	16	16	15¼	12	12½	15	10	14
Width of steam-port, in.	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1⅛	1¼	1¼	1¼
Size of exhaust-ports, in.	2½ × 14	2½ × 15	2½	2½ × 16	2½ × 16	2½ × 15½	12 × 2½	12½ × 2 5/16	15 × 2½	2½	14 × 2½
Throw of eccentrics, in.	5	4½	5	4½	5¼	5¼	5	4½	5	4½	5
Outside lap of valve, in.	¾	¾	1⅛	¾	¾	¾	¾	¾ × 1/16	¾	¾	¾
Inside lap of valve, in.	None.	1/16	None.	1/16	1/16	None.	1/16	1/16	1/16	None.	None.
Length [illegible] n.	7½	8	7	6	6	8	7	7½	16½	7	7½
Diamete[illegible], in.	4½	7	7	7	7	7	6	6	10	6½	6
Length [illegible] n.	7½	8	7	8	8	8	7	7½	......	7	7½
Diamete[illegible], in.	6½	7	7	7	7	7	6	6	......	6½	6
Size of [illegible]	4½ × 8	4½ × 7½	4½ × 7	5 × 8	4½ × 7½	5	3½ × 7	4½ × 7½	4 × 8	None.	4½ × 8
Diamete[illegible]	2	2	1½	2	2	2¼	4	1½	......	1½	2¼
Stroke o[illegible]	24	24	24	24	24	24	5	22	......	22	5
Capacity of tank, galls.	2,000	2,000	2,000	2,200	2,200	2,400	1,500	1,000	2,550	1,200	1,600
Tractive force per each pound of effective steam-pressure per square inch on the pistons, lbs.	100 7	101.1	90.8	149.5	145.4	192	78.4	101.5	146	99	70

Table showing Dimensions of Principal European Locomotives.

NUMBER OF REFERENCE.	NAME OF MAKER OR OWNER.	POSITION OF: Cylinders.	POSITION OF: Valve Motion.	POSITION OF: Frames.	PISTON: Diameter.	PISTON: Stroke	FIRE-TUBES: Number.	FIRE-TUBES: Outside Diameter.	FIRE-TUBES: Length.	HEATING SURFACE: Fire-Box.	HEATING SURFACE: Tubes.	HEATING SURFACE: Total.	Grate Area.	RATIO: Total Heating Surface to Fire-Box Surface.	RATIO: Heating Surface to Grate Area.
	Locomotives with One Driving-Axle.				Inches.	Inches.		Inches.	Ft. In.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.		
1	Great Northern Railway, Doncaster	Outside.	Inside.	Inside.	18	24	217	1 7/8	11 0	122	1,043	1,165	17.6	9.5	66.2
2	Lilleshall Company, Shropshire	Inside.	Inside.	Outside.	16	21	186	1 13/16	11 1 15/16	96.8	979.5	1,076.3	18	11.1	59.8
3	Robert Stephenson & Company, Newcastle	Inside.	Inside.	Outside.	16	22	161	2	11 4	82.9	955.1	1,088	18.9	12.5	74.6
4	Maschinenfabrik, Carlsruhe	Outside.	Outside.	Outside.	15 3/4	22	...	....	......	64.6	828.8	898.4	11.8	18.8	64.0
	Locomotives with Two Driving-Axles.														
5	Eastern Railroad of France, Epernay	Outside.	Outside.	Outside and inside.	17 23/32	25 3/16	206	1 3/4	11 5 3/4	91.4	1,133.1	1,224.5	25.6	13.8	47.8
6	Northern Railroad of France	Inside.	Inside.	Outside and inside.	17	24	201	1 49/64	11 5 23/32	100.8	975.84	1,076.2	24.56	10.6	43.8
7	Sharp, Stewart & Company, Manchester	Inside.	Inside.	Inside.	18	25	219	1 7/8	10 6 3/16	105	1,184.	1,289	17.7	11.8	70
8	Austrian State Railroad Company	Inside.	Inside.	Inside.	16 9/16	22 27/32	157	2 1/32	14 6 7/32	81.8	1,221.6	1,308	16.3	16.1	80
	Locomotives with Three Driving-Axles.														
9	Emperor Ferdinand Railroad Austria	Outside.	Inside.	Outside.	17 5/32	24 25/32	195	2 3/16	18 5 11/16	100	1,414	1,514	20.77	15.1	73.0
10	London, Brighton, and South Coast Railway Company	Inside.	Inside.	Inside.	18	20	125	1 3/4	9 8	55	470	525	10	9.5	47
11	Belgian State Railroad	Inside	Inside.	Outside.	17 23/32	23 5/8	226	1 25/32	11 4 1/2	117.8	1,060	1,178	32.3	10	36.4
12	T. A. Maffei, Hirschau, near Munich	Outside.	Outside.	....	19 1/4	26	181	2 7/16	18 5 1/4	80	1,320	1,400	16.9	17.5	82.8
13	Austrian State Railroad Company	Outside.	Outside.	Inside.	17 1/8	24 1/2	179	2 5/32	15 2 1/8	68.9	1,400	1,544	15.4	....	....
	Locomotives with Four Driving-Axles.														
14	Schneider & Company, Creuzot	Outside.	Outside.	Inside.	21 1/4	24	270	2	16 1	116.7	2,121	2,238	20.4	19.1	109
15	Sächsische Maschinenfabrik, Chemnitz	Outside.	Inside.	Inside.	17 3/8	22 7/8	199	2 3/32	15 8	101.4	1,528	1,624	18.8	16	86.4
16	Austrian State Railroad Company	Outside.	Inside.	Inside.	18 1/8	24 7/8	195	2 3/32	16 5	102.4	1,711	1,813	19.9	17.7	91.1
17	G. Sigl, Neustadt, Vienna	Outside.	Outside.	Inside.	19 11/16	24	205	2 3/32	15 7 1/2	80.7	1,291	1,372	26.24	17	52.2
	Locomotives for Mountains.														
18	Austrian State Railroad Company	Outside.	Inside.	Outside.	18 5/32	24 7/8	156	2 3/32	14 6 7/32	78.45	1,929	1,807	15.5	16.6	84.8
19	Yorkshire Engine Company, Sheffield	Outside.	....	Inside.	15	26 3/8	260	1 25/32	11 8	172.6	1,507	1,679	....	9.7	....
20	Iquique Railway, Peru	Outside.	....	Inside.	16	22	290	1 3/4	11 9 3/4	166	1,650	1,616	28	10.9	64.8
21	Belgian Company, Brussels	Outside.	Outside.	Inside.	17 5/16	19 11/16	289	1 25/32	14 9 3/4	128.5	2,199	2,327	36	18.1	64.6

Table showing Dimensions of Principal European Locomotives (continued).

NUMBER OF REFERENCE.	Outside Diameter of Boiler.	Effective Boiler Pressure.	WHEELS. Number of	Number of Driving	Total Wheel-Base.	DIAMETER OF Driving	DIAMETER OF Running	WEIGHT. Empty.	WEIGHT. Loaded.	WEIGHT. Adhesive.	Tractive Force per each Pound of Effective Pressure per Square Inch on Piston.	REMARKS.
	Inches.	Lbs.			Ft. In.	Inches.	Inches.	Lbs.	Lbs.	Lbs.	Lbs.	
1	46½	137.7	6	2	22 11½	97	49	......	88,800	33,000	80.1	With four-wheel truck in front.
2	51⅜	135.0	6	2	16 6	84	55½	60,940	69,670	27,500	64	Fig. 2880.
3	47 11/16	166.8	6	2	16 8	78	45	60,230	67,100	30,140	72.9	
4	51½	117.2	6	2	13 2½	8.½	48	52,900	58,850	26,400	65	Crampton, Fig. 2881.
5	51	137.7	6	4	17 6½	90½	57½	78,496	84,673	59,400	87.1	Fig. 2882. Paris Exposition, 1878.
6	51⅜	142	8	4	20 3 11/16	82 11/16	39⅝	84,480	91,590	59,840	88.9	With four-wheel truck. Paris Exposition, 1878.
7	60	140	6	4	16 3	78	46	......	......	......	109.8	Paris Exposition, 1878.
8	47⅝	102.5	10	4	27 5	48 1/16	37 1/16	79,300	107,800	47,480	91.4	Engerth system, tank locomotive.
9	62	142	6	6	10 7 1/16	46 11/16	....	......	78,216	78,210	155	Fig. 2883.
10	...	142	6	6	12 0	47¼	....	44,300	54,400	54,400	71.1	Tank locomotive. Paris Exposition, 1878.
11	51½	116.9	10	6	27 0½	66 11/16	41½	92,150	127,600	88,600	116.4	Tank locomotive. Paris Exposition, 1878. Fig. 2885.
12	..	..	6	6	10 5	49	....	71,500	80,800	80,800	194	
13	60	114.8	10	6	....	49½	37 1/16	88,690	116,920	66,260	146.9	Fig. 2886.
14	60½	127.5	8	8	12 5½	47¼	....	106,006	121,000	121,000	228	Vienna Exposition, 1873. Fig. 2884.
15	57½	135	8	8	11 9	42¼	....	68,600	98,170	98,170	168	Vienna Exposition, 1873.
16	56	131.2	6	8	12 5½	41½	....	87,760	96,780	96,780	152.5	
17	59	127.5	8	8	11 6½	41½	..	98,300	111,100	111,100	214	
18	45⅜	102.5	10	10	19 8 7/16	37½	....	98,600	98,500	98,500	209.1	Fink system, Fig. 2888. Paris Exposition, 1867.
19	45¼	117	12	12	29 1½	42½	....	165,600	186,400	186,400	291	Fairlie system, Grand Luxemburg Railroad Company, Belgium.
20	46⅜	...	12	12	30 6	45	....	......	120,000	120,000	250.3	Fairlie system, Fig. 2889.
21	59	139	12	12	27 7½	43	....	121,580	158,160	156,130	246.2	Meyer's system, Grand Central Railroad Company of Belgium.

the same crank; on the latter are two crank-pins, placed opposite each other or at 180°. The pistons are connected to two cross-heads, side by side, the back pistons directly through their rods, and the front pistons by means of a combination of rods which are placed on the outside, around each of the cylinders. Each cross-head is coupled with its crank-pin by a connecting-rod. The pistons move simultaneously in opposite directions, the pressures and the momenta of the moving masses being thus always counterbalanced. The desired object has been attained by this construction, but a practical difficulty has been found in the costly repairs due to the complication of parts. Other plans of double-piston locomotive engines have since been proposed, but none (1879) have been built, probably because the public is still satisfied with the present rate of speed.

To attain the same object, Haswell in Austria has produced a double-cylinder locomotive, arranged with two cylinders on each side, one above the other, acting on cranks placed relatively at 180°. The steadiness of this locomotive is great, but the complication prevented its introduction.

Mallet's Compound Locomotive.—M. Mallet, a French engineer, has designed a locomotive on the compound principle,* one of which was exhibited in Paris in the Exposition of 1878. The steam-cylinders, one on each side, are of different diameters. A releasing valve, by means of which the locomotive can be made to work as a compound or as a single-acting engine, is the only addition to the mechanism of the ordinary locomotive. Economy in fuel is claimed for this arrangement.

Mine Locomotives.—On account of the moist condition of the tracks on which they travel, these locomotives require great adhesive weight. Hence they have all their wheels coupled, and are of the tank pattern. Their dimensions in point of width and height are very limited, while their tractive force is large and their speed slow. Fig. 2891 represents a locomotive built by the Baldwin Locomotive Works, and working in a gold mine at Forest City, California. It is employed in a tunnel 4,000 ft. in length, in which is a track of only 20 in. gauge, laid with T rails, and having grades, some of which are as steep as 220 ft. per mile. The tunnel is 4 ft. wide at the track, and for 18 in. up; thence it tapers to 2½ ft. in width at the top. The extreme height from level of rails to top of tunnel is 5½ ft. The track has curves of from 60 to 150 ft. radius. Small four-wheeled cars, having wheels 12 in. in diameter and a wheel-base of 20 in., and which weigh 750 lbs. each, and can carry two tons each, are used on this track.

The following table contains the dimensions of the principal types of mine locomotives built by the Baldwin Locomotive Works of Philadelphia:

Table showing Dimensions of Mine Locomotives.

Number of driving-wheels	4	4	4
Diameter of " " in	80	80	80
Length of wheel-base, in	46	48	60
Diameter of pistons, in	8	9	10
Stroke of " in	12	12	14
Size of steam-ports, in	¾ × 7½	¾ × 7½	⅞ × 7½
Size of exhaust-ports, in	1¼ × 7½	1¼ × 7½	1½ × 7½
Travel of valve, in	2½	2¾	8
Outside lap of valve, in	$\frac{7}{16}$	⅝	⅛
Inside " " in	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{1}{8}$
Diameter of exhaust-nozzle, in	2 to 2¼	2 to 2¼	2¼ to 2¾
Diameter of boiler, in	24	28	84
Number of fire-tubes	48	52	89
Diameter of " in	1½	1½	1½
Length of " ft. and in	6 4	6 8	8 1
Width of fire-box, in	18¾	18¾	24½
Length of " in	29½	36¾	42
Height of " in	88	82	84½
Heating surface of tubes, sq. ft	105	184	284
Heating surface of fire-box, sq. ft	24	80	88.5
Total heating surface, sq. ft	129	164	822.5
Area of grate, sq. ft	5	4.5	8
Ratio of { total heating surface to fire-box surface	5.87	5.46	8.87
Ratio of { heating surface to grate-area	25.8	86.4	40.4
Length of smoke-box, in	19	19	19
Diameter of chimney, in	8	9	10
Capacity of tank, galls	200	800	180
Weight of locomotive, empty, lbs	13,000	16,000	20,000
" " loaded, lbs	15,000	18,000	28,000
Length of locomotive over all, ft. and in	15	15 6	18 8
Width of locomotive = gauge plus, in	28	80	28
Height of locomotive from top of rail to top of chimney, ft. and in.	5 8	5 2	5 5
Effective boiler steam-pressure per square inch, lbs	100 to 125	100 to 125	100 to 125
Tractive force per each pound of effective steam-pressure per square inch on the pistons, lbs	25.6	82.4	46.6

Steam-Carriages capable of running on ordinary roads have frequently been built, but have not come into general use. Reviews of the older forms of the steam-carriage will be found in "Knight's Mechanical Dictionary" and in "Reports of the U. S. Commissioners to the Vienna Exposition of 1873." The modern representative of the vehicle is the road locomotive or traction-engine, which is described under Engines, Portable and Semi-Portable.

Steam Hand-Cars are used by railway officials for making inspection of the road. The following are dimensions of one built by Mr. J. Noble of St. Louis, Mo.: Boiler vertical, height 3½ ft., diameter 18 in., steam-pressure 140 lbs.; cylinders horizontal, 3½ by 6 in. The boiler and engine are located in the middle of the platform, which is about 10 in. above the ground, and suspended below the axles. The highest speed attained was 7 miles in 15 minutes. (See *Scientific American*, xxxv., 79.)

* See *Railroad Gazette*, ix., 561.

Street-Car Locomotives.—The necessity of rapid communication in cities, and also motives of economy, have led to the employment of locomotives as motors on city railways in preference to horses. They are either separate motors, or are combined in one with the passenger car, being then

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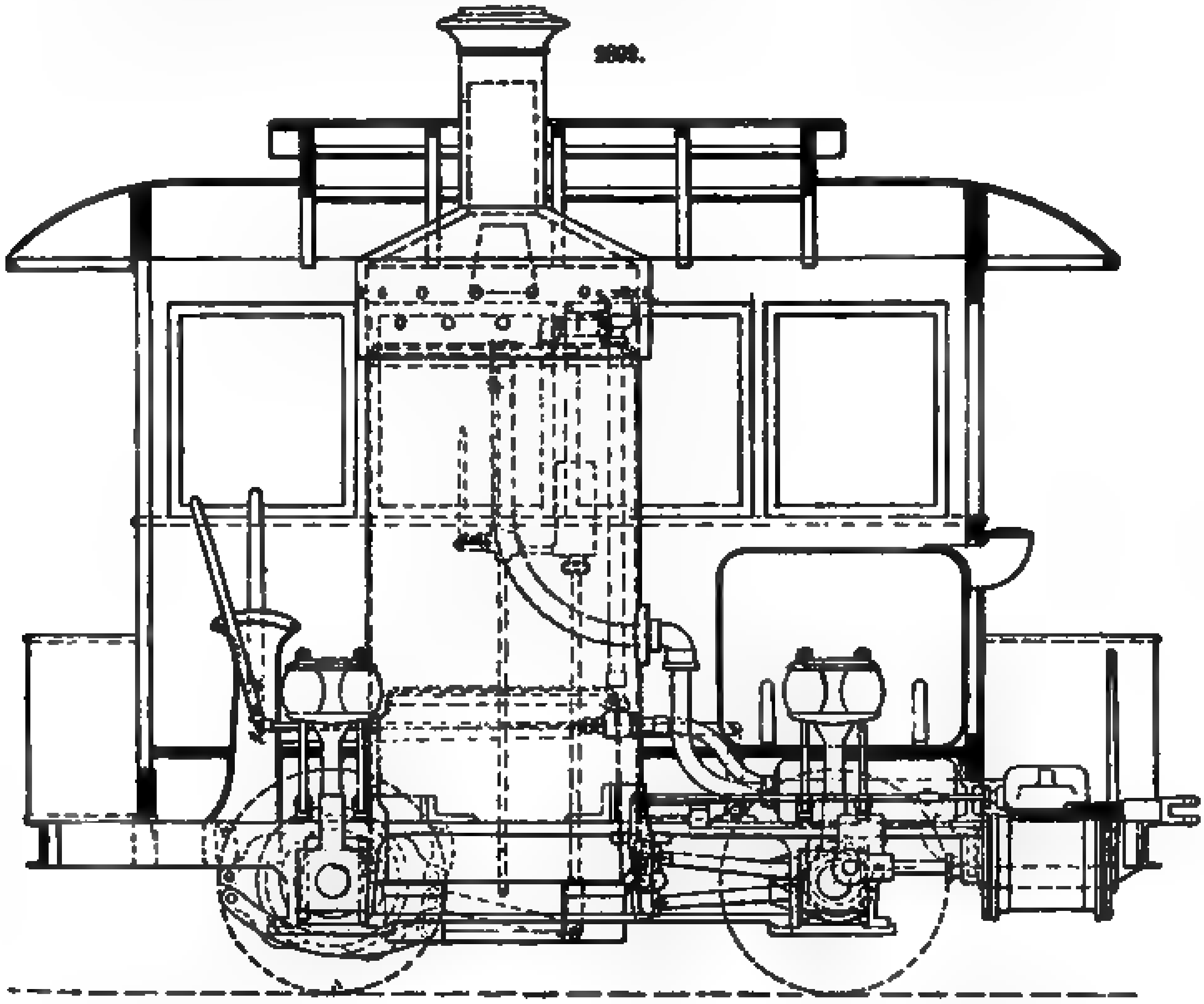


called steam-cars or "dummies." They are made noiseless by a special arrangement of exhaust, and in order not to show smoke they are made to burn coke or anthracite coal. Powerful brakes admit of stopping them in the same or in less time and a shorter space than the ordinary horse-car. In order to pass sharp curves of 25 ft. radius, their wheel-base is very short. They can attain a

speed of from 12 to 15 miles per hour, and consume from 6 to 7 lbs. of coal per mile. It has been stated that four steam motors will take the place of 68 horses, and show a saving of about $40 a day.

Fig. 2892 represents a separate motor, and Fig. 2893 a steam-car, as built by the Baldwin Locomotive Works; and the following table shows their dimensions, weights, etc.:

Table showing Dimensions, etc., of Street-Car Locomotives.

DETAILS.	Steam-Car.	Separate Motor.
Number of driving-wheels	4	4
Diameter of " " in.	30	30
Wheel-base, ft. and in.	7 6	6 6
Diameter of axle-journals, in.	5	4½
Length of " " in.	7½	5¼
Position of cylinders	Horizontal.	Horizontal.
Distance between cylinder centres, in.	66	63
Diameter of cylinders, in.	8	9
Stroke of " in.	10	10
Travel of valve, in.	2½	2½
Outside lap of valve, in.	7/16	7/16
Inside " " in.	1/16	1/16
Throw of eccentrics, in.	1¼	1¼
Length of steam-ports, in.	8	4½
Width of " " in.	¾	¾
Width of exhaust-ports, in.	1	1
Diameter of exhaust-nozzle, in.	1¾ to 2	2 to 2¼
Diameter of boiler, in.	39	34
Diameter of fire tubes, in.	1½	1½
Length of " in.	47	44
Number of "	114	86
Diameter of inside fire-box, in.	24½	25½
Height of " " in.	26	28
Heating surface of fire-tubes, sq. ft.	145.7	123
Heating surface of fire-box, sq. ft.	15	18
Area of grate, sq. ft.	2 18	4.5
Diameter of chimney, in.	7	11
Capacity of tank, galls.	100	150
Weight of locomotive, empty, lbs.	15,000	12,000
Weight of locomotive, loaded, lbs.	17,000	14,000
Length over all, ft. and in.	22	13 6
Height from rails to top of chimney, ft. and in.	11 6	9 9
Effective steam-pressure in boiler, lbs.	100 to 125	100 to 125
Tractive force per lb. of effective steam-pressure, per sq. in. on the pistons, lbs.	21.3	27

The Baxter Steam Street-Car, Figs. 2894 and 2895, is essentially similar to the preceding. The boiler is upright, and is placed on the front platform; a non-conducting partition prevents heat from entering the car. The engine, below the platform, is compound and double-acting. In ordinary use, the steam from the smaller cylinder exhausts into the larger; but in ascending grades the full pressure of the steam may be made available in both cylinders, greatly increasing the power.

Compressed-Air Locomotive.—M. L. Mekarski has successfully introduced this style of locomotive on French tramways. It consists of a reservoir containing air compressed to about 450 lbs. per square inch, which furnishes the motive power. The compressed air is admitted into the ordinary locomotive cylinders, but to improve its action it is forced through a tank of hot water of about 288° F. initial temperature, where it becomes saturated with steam, thus increasing its density and temperature. In this state the air can be used expansively without producing freezing temperatures, which would present many inconveniences. The air is admitted at a constant pressure to the cylinders by means of an equalizing throttle-valve devised by M. Mekarski, which is placed on the top of the hot-water reservoir, and is represented in section in Fig. 2896 A. This throttle consists of two chambers separated by a partition perforated with holes; under this partition is placed a rubber diaphragm, which cuts off the communication between the two chambers. The upper chamber is filled with water acted on by a piston, which can be moved up or down by means of a screw-spindle surmounted by a hand-wheel, as shown. The piston if moved down presses on the water, which pressure is communicated to the rubber diaphragm. Air inclosed in the angular space which surrounds the upper or water chamber acts as a spring, the tension of which is easily regulated by the position of the piston. The lower chamber is in communication with the chests of the cylinders, and with the top of the hot-water reservoir, from which the compressed air passes out through an opening regulated by a small conical valve. This conical valve is guided by a rod, on the top of which

is attached a flat disk which takes the pressure of the rubber diaphragm. The pressure of the air contained in the upper chamber of the throttle, acting through this disk on the valve, opens it and admits the compressed air of the reservoir into the lower chamber. It is evident that the pressures in the upper and lower chambers must be in equilibrium; in other words, as the pressure in the lower chamber falls off, the air in the upper chamber will expand, and thus move the valve down, admitting of a larger opening through which the air of the reservoir enters the lower chamber; a greater pressure in the lower chamber would compress the air in the upper chamber, acting on the rubber diaphragm from the lower side, through the disk which moves the valve upward partly closing the opening At the Paris Exposition of 1878 two of these locomotives were exhibited. One was a car-motor, with four wheels, having ten cylindrical reservoirs, 0.5 metre in diameter, containing 2,800 litres or 100 kilogrammes of air compressed to 30 atmospheres. The hot-water reservoir, containing at the starting-point 125 litres of water, at the temperature of 160° C., had the reducing-valve attached to its top. The cylinders were outside, 0.135 m. in diameter, and with 0.260 m. stroke of the piston; the wheels were 0.700 m. in diameter. The car had 17 seats and space for 18 standing passengers and the conductor. The front platform was reserved for the engine-driver. The whole car when loaded weighed about 8 tons, and could run on a level 12 kilometres (7.65 miles).

Another locomotive was a separate motor, also four-wheeled, having four reservoirs containing 5,500 litres of air compressed to 30 atmospheres. The hot-water reservoir contained 250 litres of water at 160° C. The cylinders were 0.190 m. in diameter, with 0.250 m. stroke of the pistons. It could haul on a grade of 5 in 100 one loaded passenger car, and run a distance of from 15 to 18 kilometres (from 9.32 to 11.18 miles) on the level.

The Fireless Locomotive is the invention of Dr. Emile Lamm of New Orleans, and has found a practical application, in both America and Europe, for street-car traction. The principle of its action is that heated water under steam-pressure is capable of retaining an amount of heat which, as the pressure diminishes, is disengaged, changing a portion of the water into steam. Fireless locomotives are, on this account, also known as "hot-water engines."

A fireless locomotive designed by Theodore Scheffler, several of which have been put in operation on the Crescent City Railroad in New Orleans, will be found illustrated and described in the *Railroad Gazette* of Aug. 24, 1877. See also a series of papers on the subject in *Engineering News*, February and March, 1879. Scheffler's locomotive has a cylindrical tank 31 in. in diameter and 9 ft. long, for holding the hot water. Its capacity is 300 gallons. There is but one pair of drivers, 30 in. in diameter, which are actuated by pistons at two cylinders of 4½ by 10 in. The tank is charged with water from a stationary boiler, heated up to a temperature of 390°, which is that corresponding to a pressure of 220 lbs per square inch. With such a charge the engine can propel the machine over a distance of six miles, drawing an ordinary loaded street-car, the pressure of the tank at the end of the run being reduced to about 40 lbs.

The fireless locomotive has been somewhat improved by the addition of a furnace to the hot-water reservoir, into which a few shovelfuls of ignited coal are thrown at the departure from the starting-station. The fuel burns slowly, thus compensating partly for the losses of heat. A proportionate reduction of the amount of hot water in the reservoir is made.

Dimensions, Weights, etc., of Standard Engines used on Pennsylvania Railroad.

NUMBER.	DETAILS.	I. CLASS A. Passenger Engine with Tender.	II. CLASS B. Passenger Engine with Tender.	III. CLASS C. Passenger Engine with Tender.	IV. CLASS C. Passenger Engine with Tender.	V. CLASS D. Freight Engine with Tender.
1	Number of pairs of driving-wheels	2	2	2	2	3
2	Diameter of driving-wheels, in	68	62	62	62	56
3	Total wheel-base, ft. and in	22 5¼	22 3¼	22 5¼	22 5¼	23 8
4	Length of rigid wheel-base, ft. and in	8	8 6	8 6	8 6	12 5
5	Diameter of driving-axle bearing, in	7	7	7	7	6½
6	Length of driving-axle bearing, in	7½	7½	7½	7½	7½
7	Diameter of main crank-pin bearing, in	3½	3½	3½	3½	4
8	Length of main crank-pin bearing, in	3½	3½	3½	3½	4
9	Number of wheels in front truck	4	4	4	4	4
10	Diameter of wheels in front truck, in	30	28	28	28	28
11	Type of truck	Swing-centre.	Swing-centre.	Swing-centre.	Swing-centre.	Swing-centre.
12	Position of cylinders	Outside.	Outside.	Outside.	Outside.	Outside.
13	Width from outside to outside of cylinders, in	81	81	81	81	81
14	Diameter of cylinders, in	17	18	17	17	18
15	Length of stroke, in	24	24	24	24	22
16	Travel of valve, in	5	5	5	5	5
17	Outside lap of valve, in	¾	¾	¾	¾	¾
18	Throw of eccentrics, in	5	5	5	5	5
19	Length of steam-ports, in	16	16	16	16	16
20	Width of steam-ports, in	1¼	1¼	1¼	1¼	1¼
21	Width of exhaust-ports, in	2½	2½	2½	2½	2½
22	Thickness of boiler-plates and dome, in	5/16	5/16	5/16	5/16	5/16
23	Thickness of outside fire-box slope, in	⅜	⅜	⅜	⅜	⅜
24	Thickness of waist and smoke-box, in	⅜	⅜	⅜	⅜	⅜
25	Maximum internal diameter of boiler, in	50	51¼	51¼	51¼	5 ¼
26	Minimum internal diameter of wagon-top, in	48½	48½	48½	48½	48½
27	Height to centre of boiler from top of rail, in	76	74	74	74	73
28	Number of tubes	142	155	155	163	119
29	Inside diameter of tubes, in	2	2	2	1¾	2¼
30	Outside diameter of tubes, in	2¼	2¼	2¼	2	2½
31	Length of tubes between sheets, in	131 3/16	127 13/16	127 13/16	125 3/16	152 13/16
32	Length of fire-box bottom (inside), in	66¼	72¼	72¼	119¼	59¼
33	Width of fire-box bottom (inside), in	35	35	35	34¼	35
34	Height of crown-sheet above top of grate, in	60½	60½	60½	52	57½
35	Inside fire-box material	Steel.	Steel.	Steel.	Steel.	Steel.
36	Thickness of fire-box sheets, sides, in	¼	¼	¼	¼	¼
37	Thickness of front, back, and crown, in	5/16	5/16	5/16	5/16	5/16
38	Thickness of tube sheets, in	½	½	½	½	½
39	External heating surface of tubes, sq. ft	92).52	941.87	941.87	1,002.60	997.25
40	Internal heating surface of tubes, sq. ft	815.4	858.70	858.70	878.45	886.55
41	Fire area through tubes, sq. ft	3.16	3.37	3.37	3.05	3.28
42	Fire-grate area, sq. ft	16.1	17.6	17.6	29.18	14 5
43	Heating surface of fire-box, sq. ft	131.72	115.11	115.11	158.55	95.97
44	Total heating surface with external area of tubes, sq ft	1,052.24	1,056.98	1,056.98	1,161.15	1,093.22
45	Total heating surface with internal area of tubes, sq. ft	947.12	973.51	973.51	1,036.95	982.52
46	Fire-grate area divided by tube area, ft	5.09	5.22	5.22	9.55	4.42
47	Minimum diameter of smoke-stack, in	18	18	18	18	18
48	Height of stack from rail, ft. and in	14 8	14 8	14 8	14 8	14 8
49	Size of exhaust nozzle, in	2½ × 3½	2½ × 3½	2½ × 3½	2½ × 3½	2½ × 3½
50	Least sectional area of chimney, sq. ft	1.767	1.767	1.767	1.767	1.767
51	Fire-grate area divided by least sectional area of chimney, ft	9.11	9.96	9.96	16.48	8.20
52	Total tractive force with effective pressure of four-fifths boiler, lbs	10,200	12,542	11,188	11,168	12,792
53	Nature of fuel, coal	Bit.	Bit.	Bit.	Anth.	Bit.
54	Weight of engine empty, lbs	65,200	67,100	66,800	68,680	68,500
55	Weight of engine in service, lbs	71,900	76,850	75,500	78,750	77,400
56	Capacity of tank, galls	2,400	2,400	2,400	2,400	2,400
57	Capacity of coal-tank, lbs	8,000	8,000	8,000	8,000	8,000

LOCOMOTIVES, INSPECTION AND DRIVING OF. It is a matter of the greatest importance that the locomotive should be carefully inspected, and all inaccuracies in its construction discovered before it is set to work; and this not only when it is new, but also before every trip. It is a matter of greater difficulty than is usually supposed to manage a locomotive so as to secure it the longest life, by preventing all the unnecessary wear that it is possible to obviate, by detecting all causes from which an accident might result while on the run, and by working the engine with the best economy in fuel and lubricants. Many books have been written on this special subject, but they are far from being exhaustive. Locomotive driving, like seamanship, must chiefly be learned by practical experience. In this article, therefore, we can only touch upon the more salient points of the subject.

The boiler, when first built, and periodically afterward, should be tested under cold-water pressure, to show all the leaking spots which can be secured by calking. Testing under steam should follow. It is not intended, of course, to find out whether the boiler will explode, as so crucial an experiment might well result in a disaster, more dangerous when occurring in a crowded shop than on the open road. The pressure should be gradually increased, and close attention paid lest a brace, or a stay-bolt, or a rivet break during the test. The boiler should be frequently and minutely examined all over, and it is well to sound the stay-bolts with a light hammer in order to detect breaks in them. Sounding of stay-bolts, however, is not a very reliable means of determining rupture; and a careful engineer will always if possible inspect them from the inside. The best means of providing for the discovery of broken stay-bolts is to make them hollow, a hole being

Dimensions, Weights, etc., of Standard Engines used on Pennsylvania Railroad (continued).

Number.	Details.	VI. Class E. Freight Engine with Tender.	VII. Class F. Shifting Engine with Saddle Tank.	VIII. Class G. Passenger Engine with Tender.	IX. Class H. Shifting Engine with Tender.	X. Class I. Freight Engine with Tender.
1	Number of pairs of driving-wheels	3	3	2	3	4
2	Diameter of driving-wheels, in	50	44	56	44	50
3	Total wheel-base, ft. and in	23 8	9 9	19 9½	9 10	21 6
4	Length of rigid wheel-base, ft. and in	12 8	9 9	7	9 10	18 8
5	Diameter of driving-axle bearing, in	6½	6½	6½	6½	6½
6	Length of driving-axle bearing, in	7½	7½	7½	7½	7½
7	Diameter of main crank-pin bearing, in	4	3½	4	3½	4½
8	Length of main crank-pin bearing, in	4	3½	4	3½	5
9	Number of wheels in front truck	4	..	4	..	2
10	Diameter of wheels in front truck, in	26	No truck.	26	No truck.	28
11	Type of truck	Swing-centre.		Swing-centre.		Half truck.
12	Position of cylinders	Outside.	Outside.	Outside.	Outside.	Outside.
13	Width from outside to outside of cylinders, in	81	81	81	81	84
14	Diameter of cylinders, in	18	15	15	15	20
15	Length of stroke, in	22	18	22	22	24
16	Travel of valve, in	5	4	4	4	5
17	Outside lap of valve, in	¾	¾	¾	¾	¾
18	Throw of eccentrics, in	5	5	5	5	5
19	Length of steam-ports, in	16	12	12	12	17½
20	Width of steam-ports, in	1½	1	1	1	1½
21	Width of exhaust-ports, in	2½	2	2	2	2½
22	Thickness of boiler-plates and dome, in	5/16	5/16	5/16	5/16	5/16
23	Thickness of outside fire-box slope, in	⅜	⅜	⅜	⅜	⅜
24	Thickness of waist and smoke-box, in	⅜	⅜	⅜	⅜	5/16
25	Maximum internal diameter of boiler, in	51½	4 ½	46½	47½	5 ½
26	Minimum internal diameter of wagon-top, in	48½	42¾	44¾	44¾	58¾
27	Height to centre of boiler from top of rail, in	71	6 ½	70	6 ½	77
28	Number of tubes	128	89	180	91	188
29	Inside diameter of tubes, in	1¾	2	1¾	2¼	2¼
30	Outside diameter of tubes, in	2¼	2¼	2	2½	2½
31	Length of tubes between sheets, in	146 13/16	149 13/16	115	15 ⅜	155 13/16
32	Length of fire-box bottom (inside), in	67½	44½	5 ½	54½	96
33	Width of fire-box bottom (inside), in	35	35	35	35	34½
34	Height of crown-sheet above top of grate, in	57½	45	52½	46½	42¾
35	Inside fire-box material	Steel.	Steel.	Steel.	Steel.	Steel.
36	Thickness of fire-box sheets, sides, in	¼	¼	¼	¼	¼
37	Thickness of front, back, and crown, in	5/16	5/16	5/16	5/16	5/16
38	Thickness of tube sheets, in	½	½	½	½	½
39	External heating surface of tubes, sq. ft	984.83	651.22	652.81	776.13	1,158.65
40	Internal heating surface of tubes, sq. ft	885.6	578.5	574.0	699.79	1,043.28
41	Fire area through tubes, sq. ft	3.39	1.93	2.17	2.51	3.75
42	Fire-grate area, sq. ft	16.34	10.7	13.3	13.2	23
43	Heating surface of fire-box, sq. ft	111.27	61.29	69.04	79.11	100.91
44	Total heating surface with external area of tubes, sq. ft	1,096.10	712.51	721.85	855.24	1,259.56
45	Total heating surface with internal area of tubes, sq. ft	996.87	629.79	640.04	778.90	1,144.19
46	Fire-grate area divided by tube area, ft	4.85	5.54	6.13	5.23	6.16
47	Minimum diameter of smoke-stack, in	18	15	17	15	20
48	Height of stack from rail, ft. and in	14 8	14	14 8	14	15 11
49	Size of exhaust-nozzle, in	2½×3½	2½×3	2½×3	2½×3	3×4
50	Least sectional area of chimney, sq. ft	1.767	1.227	1.576	1.227	2.181
51	Fire-grate area divided by least sectional area of chimney, ft	9.24	8.72	8.50	10.8	10.54
52	Total tractive force with effective pressure of four-fifths boiler, lbs	14.256	92.045	8,839	11.250	19,200
53	Nature of fuel, coal	Bit.	Bit.	Bit.	Bit.	Anth.
54	Weight of engine empty, lbs	69.200	52,500	54,150	58,100	82,130
55	Weight of engine in service, lbs	75,600	63,500	60,000	60,450	91.640
56	Capacity of tank, galls	2,400	820	1,600	2,200	3,000
57	Capacity of coal tank, lbs	8,000	1,500	6,500	5,000	8,000

T. F. K.

drilled through them longitudinally. This aperture opens to the inside of the fire-box, but is closed on the outside. When the stay-bolt breaks, it at once leaks to the inside, and is thus easily found.

All scale formed in the boiler should be thoroughly scraped off, as it prevents evaporation and may cause explosion. It is well therefore to have as many hand-holes as may be necessary, to give free admission to all parts of the boiler where the scale usually forms. Frequent washing out of the boiler is very important, and should never be neglected. The fire-tubes should be kept clean from sediment, and a good way to do this is to blow steam through them often. The smoke-box and also the smoke-stack, if it has a spark-collector, as on the wood-burning locomotives, should also be cleaned from fallen sparks. The netting of the smoke-stack, if injured, should be mended, as pieces of inflamed fuel thrown out set buildings or woods on fire. Many "mysterious" conflagrations along railroads are thus caused. The grate and the ash-pan should be kept clean. In fact, cleanliness is a prime virtue in those in charge of locomotives, and should be rigidly demanded all over the machine. Dirt or rust on his engine is the sure sign of a negligent driver. The throttle-valve and the steam-pipes should not be allowed to leak. Leaks in the first are easily discovered by the steam escaping from the cylinder-cocks, when these are open and the throttle-valve is closed. The safety-valves should be frequently inspected to render it certain that nothing prevents their blowing-off at the required pressure. The injectors should be tried while the locomotive is in the round-house, and the pumps should be tested immediately after leaving the house, by means of the pet-cock. The

tender, as well as the pipes and valves which control its communication with the feeding apparatus, should be kept free from sediment. The slide-valves, if not tight, will admit of steam leaking through the cylinder-cocks when placed in their middle position, and will thus reveal the fact. The same thing will occur if the piston-packing rings are not set up sufficiently tight, the steam blowing from the admission side to the exhaust, and escaping through the open cock. Care, however, should be taken not to set the piston-rings too tightly, as this would cause friction and heat which would melt the soft metal in them. The stuffing-boxes should be packed only sufficiently tight not to admit of the steam leaking through them. It is well to clean the cylinders and steam-chests, by blowing steam and water through them, for which purpose the cylinder oil-cups can be used. All the moving parts of the mechanism—in fact, wherever wear is taking place, as on the cross-heads, slides, or connecting-rod brasses—should be carefully watched, so that no lost motion may exist. Care must be taken in adjusting the connecting-rod brasses, so that they shall be neither too loose nor too tight, as in the latter case they would heat. The coupling-rods should have their brasses carefully adjusted to prevent the distance of their centres from being changed from what it should be, namely, from the distance of the centre of the axles. It is of the utmost importance that all the moving parts should have their true centre-lines. The centre-lines of the cylinders should be square to the centre-lines of the axles, which last must thus be parallel to one another. This is provided for when the new locomotive is being erected, but a good engine-driver will always satisfy himself of the fact. Not less important is it that the cranks are of equal length and square. This can be ascertained by a special instrument made for this purpose.* The eccentrics should be square to the axle; and in a word, throughout all the mechanism the centre-lines must be true with the direction of motion.

Adjusting Centre-Lines.—The centre-lines of the cylinders and the axles are adjusted by means of the frames. This is accomplished as follows: The boiler is placed so that its axial line is horizontal; the frames are then placed and attached parallel with it, their horizontal position being ascertained by a spirit-level. Plumb-lines thrown over the boiler admit of measuring their lateral position. The two frames of the locomotive require also to be so adjusted that the centre-lines of the axles, and also the line connecting the centres of the opposite pedestals, shall be square to the frame. The cylinders are then set, their centre-lines being found and marked with a string, which should be parallel with the frame and at the required distance from it. If the centre-line of cylinders is to be inclined, the angle is measured. The excellence of the machine-tools used at the present time guarantees largely the accuracy of erection. Surfaces can easily be planed square to each other, and the holes drilled square to the surfaces.

Setting of the Slide-Valves is accomplished in the following manner: The valve with its stem is placed so that the edge of one steam-port is just opened to the steam; a mark is then made on the stem, on the outside, and also on the gland, and the distance between the two taken between the points of a trammel. The valve is then moved far enough just to open with its edge the other steam-port, and a second mark is made on the stem, equally distant from the mark made on the gland in the first case, as kept in the trammel. A gauge is then specially made, which gives this distance, and by means of which the engine-driver can always ascertain the position of the valves without taking off the steam-chest cover. The valves are then connected to the motion, and everything arranged in the working order, the locomotive being, however, lifted up to admit of easy turning of the wheels. The reversing lever is placed in that notch in which the locomotive is expected to do the most of its work. The dead centres of the crank are found by turning the wheels until the cross-head is near the end of its stroke, and a mark on the guide-bars is made to enable the cross-head to be put again in the same position. A mark on the frame and on the wheel-tire is also made in this position, and the distance between these two marks is taken on the trammel. The wheel is then turned to pass the dead centre, until the cross-head comes back again into the marked position. One point of the trammel is then placed in the mark on the frame, and with its other point a second mark on the tire is made. It is evident that if the centre of the distance between the two marks on the tire is marked, and the wheel is turned until one point of the trammel falls into it, while the other is in the fixed mark of the frame, the crank-pin is exactly in one of its dead centres. The crank being in the dead centre, the valve is set to give the required lead; then the crank is set in its other dead centre, and the lead measured by means of the marks on the valve-stem; and if not correct it is corrected, usually by lengthening one of the eccentric rods. The whole distribution of steam in the cylinders can thus be ascertained with the utmost exactness. It is important that the setting of valves be tested from time to time, and always after disconnecting them.

In inspecting a locomotive, all bolts, nuts, keys, and pins should be examined to see that they are securely fastened, especially on all the moving parts. The springs and their hangers, and the wheels and tires, should also be examined, and sounded to discover ruptures. Attention should be given to the lubrication. It should be made certain not only that the lubricators are filled, but that the oil or grease is flowing on the bearing surfaces. Brakes, whether hand, air, or vacuum, should be tested as soon as the locomotive leaves the house. A very complete set of fireman's and driver's tools, instruments, etc., should always be on the locomotive or the tender. In the following list the most important are named: A coal-shovel, coal-pick, and long-handled hoe and poker; a pair of jacks, either screw or hydraulic; chains, rope, and twine, to be used in case of accident; a heavy pinch-bar for moving the engine; a small crow-bar; oil-cans with short and long spouts, and another smaller one with spring bottom; a steel and a copper hammer; a cold and a cape chisel; a hand-saw, axe, and hatchet; one large and one small monkey-wrench, and a full assortment of solid wrenches for the bolts and nuts of the engine; cast-iron plugs for plugging tubes, with a bar for inserting them; two sheet-iron pails or buckets; different-colored lanterns and flags, according to the colors used for signals on the line; and a box with a half-dozen torpedoes. Besides these implements, the following

* See *Railroad Gazette*, 1878, x., 550.

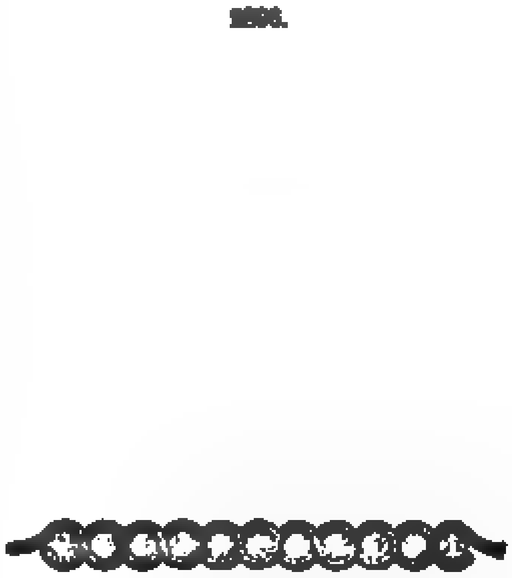
duplicate parts should always be on hand, to be used when wanted: Keys, bolts, and nuts for connecting-rods; split-keys, wedge-bolts, and bolts for oil-cellars of driving and truck boxes; driving and truck spring-hangers; wooden blocks for fastening guides in case of accident; blocks for driving-boxes and links; a half-dozen ⅜-in. bolts, from 6 in. to 2 ft. long, to be used in case of accident; two extra water-gauge glasses; and two glass head-light chimneys.

Locomotive Driving.—On starting the locomotive, after a close inspection of all the parts as above described has been made, the engine-driver should assure himself that the water in the boiler is at its proper height, and that the fire is in a good condition; otherwise it is difficult to keep up the steam. To fire a locomotive well is a more difficult matter than is supposed, and requires no small amount of intelligence. Steam should be kept as much as possible at uniform pressure. See also that the least possible amount of steam is blown off at the safety-valves, for all there escaping is wasted. The fireman as well as the driver should know the grades of the road, and should store up the steam before entering the grade, by having the boiler well filled with water, and a good fire ready. A light fire should be maintained when descending a grade or when a stop is to be made. The heaters should not be left idle when stopping, especially in winter, but through them the surplus of steam should be used in heating the water in the tender. The engine-driver should regulate the power, not by wire-drawing of steam through the throttle-valve, but by cutting off the admission of steam to the cylinders, thus getting all the advantages of expansion and economizing fuel. He should watch carefully the height of the water in the boiler, by repeated examinations of the water-gauges, and note frequently the working condition of pumps or injectors. He should open the cylinder-cocks whenever he has reason to suppose that there is water collected. In a word, while at his post his attention should be constantly on the alert; for on his courage, skill, and presence of mind the safety of the train depends.

Accidents while on the Road.—Should anything require a quick stopping of the train, the brakes should be immediately applied, the engine reversed cautiously, with the cylinder-cocks partly open at first, so as to prevent the bursting of cylinders or other parts, and the sand-pipes open to increase the adhesion of the wheels so that their reversed motion may the sooner check the speed. Should any part of the engine mechanism break, as for instance a cylinder-piston or its rod, connecting-rod, cross-head, or a part of the valve motion, so that it cannot be made to work, the injured engine must be disconnected and its piston secured from moving. The valve must be fastened in its middle position, so as to cover both steam-ports of the cylinder, and the locomotive should then be worked with only one engine. If one of the coupling-rods is taken off, that of the other side must not be left in its place. If a spring or hanger is broken, a wooden block placed between the frame and the axle-box is a good temporary remedy. In case of an injury to a wheel, it must be lifted from the track, by placing a block under the axle-box. Should an eccentric slip on the axle, it can be fastened again as follows: Disconnect the valve-rod from the rocker, and place the crank at the dead centre as nearly as possible; then move the valve into position of the lead, and turn the eccentric on the axle until the position is caught in which the valve-rod may be again connected with the rocker, without the valve being moved. The bursting of a fire-tube is remedied by plugging it up. There are numerous other common accidents that happen, the remedies for which depend upon circumstances, or upon the ingenuity and skill of the engine-driver. T. F. K.

LOOMS, CONSTRUCTION AND USE OF. Weaving is the art of interlacing threads or other fibres in such a manner as to form a continuous fabric. A loom is a mechanical contrivance for accomplishing this. If a piece of plain cloth or calico be examined, it will be found to consist of a number of threads placed parallel to each other, which are interlaced alternately by a single thread passing from side to side of the cloth, Fig. 2896. This separate thread which runs crosswise the fabric is usually called the *weft* or *woof*. The lengthwise threads are called the *warp*. The warp-threads are usually much finer than the weft-thread, and the fibres are usually spun together in a similar manner to a two- or three-stranded cord. The weft-thread, on the contrary, is but slightly spun, and consists ordinarily of but one strand. By this means the weft is made soft and yielding, and is better adapted to fill the interstices of the cloth; while the warp-thread is made firmer, and not only adds more strength to the fabric, but is much better suited to undergo the weaving process. In the throwing or spinning of silk (see Silk Machinery) this difference of twisting is expressed by calling the weft-thread "tram," and the warp, owing to its excessive twist, is termed "organzine."

2896.



The essential portions of all looms are as follows: 1. A substantial frame for holding the warp; 2. Means for separating the threads of the warp to admit of the passage of the weft, and of so governing the warp-threads as to cause them to interlace with the weft in the desired manner; 3. A means of carrying the weft-thread horizontally across and between the warp-threads while the latter are suitably opened; 4. A means of forcing or packing the weft tightly into the angle formed by the opened warp, and so rendering the fabric tight and compact.

It will be observed that in the last three requirements the chief operations of weaving are briefly summed up, namely: the opening of the warp, the passage of the weft, and the beating of the weft into position. Then the warp opens again, an interchange of its threads occurs, and the same operations are repeated. The simplest means of meeting these demands exists in the old hand-loom, which is still often used in weaving silk, rag carpets, and various home-made fabrics, and the princi-

pal parts of which are common to all looms. In describing the various processes of weaving, such mechanism as is essential to them, and only devices found in all weaving apparatus, are detailed. Under Looms, Power, are given the various modern forms of loom by which these processes are carried out.

In every loom, between opposite ends of the framework are placed two cylindrical beams, *A* and *B*, Fig. 2897. The beam *A* is the *warp-beam*, on which the warp is wound, and *B* is the *cloth-beam*, upon which the cloth is wound as it is woven. The warp-threads are placed parallel to each other, and are carried from the warp-beam *A* and attached to the cloth-beam *B*. This is done by threading the knotted ends of the threads upon a small rod or lath, wedging it into the slot or groove formed

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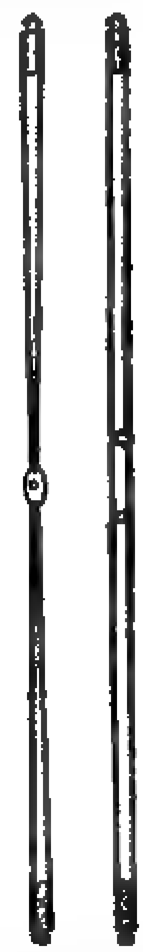

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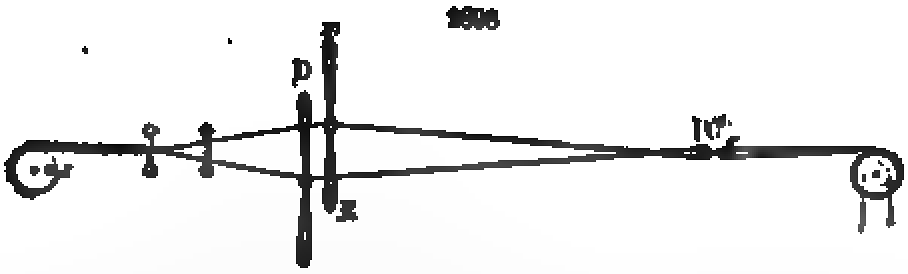

in the beam *B* for that purpose, which is shown in section at *x*, Fig. 2898. In order to keep the threads in their relative position and parallel to each other, two rods are inserted between the warp-threads *C*, in such a manner that each thread passes *over* one of the rods and *under* the other alternately, as shown. Thus a cross or lease is formed by the threads between the two rods, which not only keeps the threads in proper order, but enables the weaver to detect with ease the proper position of any broken thread he may have to repair. This arrangement of the threads is formed during the process of warping. After the warp has passed the lease it is then passed through *the heddles*, as shown at *D* and *E*, Fig. 2899. The heddles are composed of a number of threads stretched between two *laths*, *G*, Fig. 2897, and they have loops made in the middle of them, or an eye called a *mail* is threaded upon them instead. These loops or eyes are for the purpose of passing the warp-threads through. There are two heddles shown, one of which receives every alternate thread of the warp, and the other receives the remainder. If either of them be raised, it will also raise the warp-threads which have been threaded through the loops or mails of it, and thus make an opening or *shed*, as it is usually called, for the passage of the shuttle. Heddles are made of various forms, materials, and strength, according to the particular fabric or purpose for which they are required. In Fig. 2899 are shown two common modes of forming them, one with a loop and the other with an eye or mail. For weaving silk warps, the mails are usually made of glass; but for cotton and other materials, steel or brass is generally used. The healds or heddles are made by means of very ingenious machines, known as heald-knitting or -making machines. The upper laths of each heddle are connected to cords which pass over pulleys as shown, and thus they balance each other. The arrangement of laths and heddles is called the *loom-harness*. The lower laths are connected with the treadles *M*, by means of which the heddles are alternately raised and lowered.

The warp-threads, after they have been threaded through the heddles, are passed through the *reed* *P*, which is composed of narrow strips of metal or flattened wire. These strips were formerly of reed, and hence the name. The reed is fixed into the lower part of a frame, called the *batten*, Fig. 2900, which is suspended from two *gudgeons*, and is capable of being moved a short distance to and fro, in a line parallel to the warp-threads. At each side of the batten, and about level with the bottom of the openings in the reed, are placed two shuttle-boxes, *g g*. These boxes have a spindle fitted lengthwise over the centre of them, upon which the picker, a kind of hammer, is made to slide. The two pickers are connected together by a slack cord *m*, to the centre of which the "picking-stick" is attached. Two short ends are connected to the picker-cord to keep it suspended and free to work. The boxes are suited to the size of the shuttle, which is driven with considerable

velocity from one box to the other by means of the picking-stick and pickers. It is known as the fly-shuttle, and was patented by John Kay in 1733. Fig. 2900 shows the batten detached from the loom, in which *pp* are the pickers, which slide upon the spindles *n n*, *s* the shuttle placed in the shuttle-box. The pickers are variously made, but principally of hide dressed so as to resemble horn.

The loom being ready for the actual operation of weaving, the weaver takes his seat, and places the shuttle in one of the boxes, after pushing the picker back to the far end of the box. A short length of the weft-thread is allowed to hang out of the eye of the shuttle, so that it may be caught on the edge of the warp as the shuttle enters the shed for the first time. He then takes hold of the batten by the left hand in the position shown in Fig. 2900, and holds the picking-stick in his right hand. The shuttle is shown to be in the right-hand box; in this case the weaver places his right foot upon the right treadle, and depresses it, which causes the left treadle to rise, and an opening or shed is formed in the warp, as shown. He first pushes the batten backward a few inches, which causes the opening in the warp to appear in front of the reed as well as at the back, and thus gives room for the shuttle. He next, with a smart jerk of the right hand, throws the shuttle through the warp and into the opposite shuttle-box, where it comes into contact with the picker, and drives it to the far end of the box. Then he draws the batten toward him, which brings with it in front of the reed the weft-thread. He then treads upon the left treadle, and at the same time pushes the batten backward, which opens the shed ready for throwing the shuttle back to the right-hand box. When the shuttle is thrown he again draws the batten toward him, which pushes the weft-thread against the last thread, or shute. Thus the operation is continued by repetitions of the three motions necessary to the production of cloth, viz., opening the shed by means of the treadles, throwing the shuttle, and beating together the weft-threads by the reed which binds them together compactly and evenly.

Although the fly-shuttle has been in use since 1733, the old mode of throwing the shuttle by hand is in frequent use, principally among silk-weavers. The fly-shuttle is made straight in form, as shown in Fig. 2901. It is usually made of boxwood, and is tipped at each end with smooth steel points. There is an oblong hole mortised out of the shuttle for the reception of the weft-bobbin. In silk-weaving this bobbin is called a quill, but is generally made of a small reed about the length of a quill-barrel. The reed still retains the name of quill, although quills are not used now, owing to their extra cost. Two small wire springs are attached to the quill, which cause a light friction and thereby a slight tension of the thread. The weft-thread is made to pass out at the side of the shuttle through an eye made of glass or earthenware, which is fixed there for the purpose.

The shuttle when thrown by hand is somewhat curved, as shown in Fig. 2902, that form being more suitable to follow the motion of the hand. In throwing it, the thumb is placed on the shuttle-race, while the hand is held open below to catch the shuttle. The batten is drawn toward the weaver by the thumb, although it naturally falls toward him by its own gravity, being usually worked a little out of the vertical line for that purpose. Sometimes springs are placed to draw the batten forward, in which case the weaver with the back of the hand merely pushes the batten backward, while the spring gives the blow.

Let-off and Take-up Motions.—It has been shown that the ends of the warp-threads are secured to the cloth-beam by being inserted into a groove. In the hand-loom the beam is held in position

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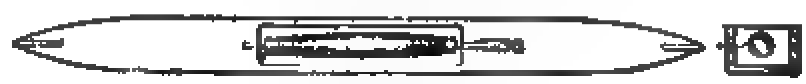

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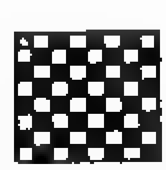

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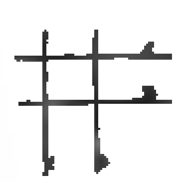

by means of a ratchet-wheel and pawl, and as the cloth is woven it is wound up by a short lever. In order to keep the warp-threads of a proper degree of tension, the warp-beam is shown provided with two weights, or two pairs of weights, one being much heavier than the other, and attached to the same cord, the heaviest weight being hung so as to draw the warp in a contrary direction to the

cloth-beam, and thereby cause the tension upon the threads. The rope to which the weights are attached is wound around the warp-beam several times to give it sufficient friction. Now, when the treadles are depressed and the shed is opened for the passage of the shuttle, the heavier weight is slightly raised and falls again, when the shed is closed. As the cloth is woven, the weight is gradually drawn upward, and the small counterpoise falls. When this latter touches the ground, it follows that its rope becomes slackened, and thereby takes the friction off the other rope and allows the warp-beam to move, although the tension caused by the heavier weight is always acting upon the warp. This motion is made in many different forms—sometimes by means of levers, in which case the weights can be adjusted to any degree of tension. The tension becomes greater as the warp is unwound, through the diameter of the beam being lessened, while the weight remains working at the same leverage. Thus it requires occasional adjustment in weaving very long warps, where the diameter of the warp-beam may become lessened perhaps one-half. This circumstance has given rise to let-off motions being continued to equalize the strains. These will be more specifically referred to under LOOMS, POWER.

In like manner the take-up motion is effected. In hand-loom weaving, the weaver draws the cloth-beam round occasionally, after weaving a few inches. In power-loom weaving this becomes a very important matter, and a great variety of motions have been invented to perform it.

The Temple.—In the process of weaving it is found that some cloth has a tendency to draw in or become narrow. This effect must be counteracted, otherwise very irregular work will be the result. The contrivance used for the purpose is called a temple, and has been made in a great variety of forms. The device used in the hand-loom is represented in Fig. 2903. It consists of two flat pieces of wood, adjusted and laced together according to the width of the cloth by a cord as shown. At both ends of the temple a number of pin-points are fixed. These points are placed in the two selvages of the cloth, and it is thereby held stretched out and prevented from contracting, as it otherwise would do. As the cloth is woven the temple is moved. In power-loom weaving the temples are made to revolve so as to require no refixing as the cloth is woven.

PLAIN WEAVING.—Each throw of the shuttle is called a "pick;" consequently the loom is counted in speed by the number of "picks" per minute. The number of weft-threads also is named in the same way, and is counted as so many picks to the inch. In Fig. 2896 a piece of plain woven cloth is represented, as before stated. Fig. 2904 represents the same thing as it would be drawn by the designer, and it is generally called "tabby" or plain weaving. In arranging the loom, the weaver employs another method of drawing the pattern, and in this case he would represent it as shown at Fig. 2905, in which A and B represent the two heddles, and 1 and 2 the treadles. The marks placed at the intersection of the lines show which of the treadles and heddles are connected together. This method becomes a matter of great importance when a number of heddles are used, as will be shown hereafter.

In plain weaving, the first step toward figured or pattern weaving is made by varying the thickness of the threads both in the warp and the weft, as may be observed in the borders of some cambric handkerchiefs. Different-colored warp- and weft-threads may also be used so as to form stripes, checks, or plaids; or material of different kinds, such as silk and wool, may also be used with more or less effect. Whatever the difference of the threads may be, the actual mode of weaving them is simply plain or tabby weaving. If various kinds of threads are required for the warp, they are arranged in the process of warping, and they are afterward entered or placed in the loom accordingly. But the various kinds of weft-threads are inserted by shuttles, each description of thread having a separate shuttle.

When the fly-shuttle was first introduced, it was intended for the use of one shuttle only; but it was afterward found that if two or more shuttles could be used on the same principle, it would be of great advantage. This was effected about the year 1760 by Robert Kay, the son of the inventor of the fly-shuttle, who invented the "drop-box" for that purpose.

The drop-box is usually made for two shuttles only, although by an ingenious contrivance three shuttles can be used, or several more, by an extension of the same principle. It will be advisable

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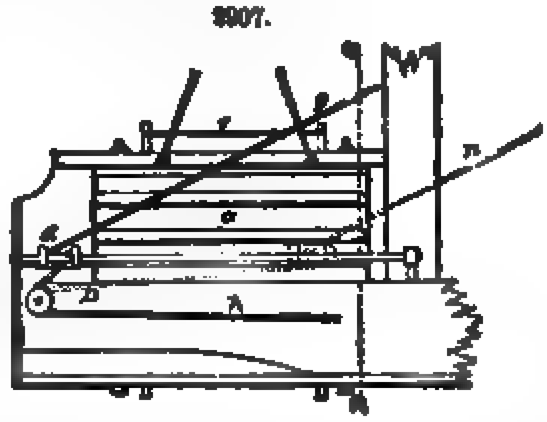


to describe a three-shuttle drop-box, for it comprises the principles of both the others. Fig. 2906 shows a front view of a batten fitted with boxes $a\,a$. Fig. 2907 is an elevation of one box on a large scale, and Fig. 2908 is a section of it at the line $B\,B$. The drop-box consists simply of a small board upon which are fixed three or more shelves, according to the number of shuttles; and as these shelves are lowered to the level of the shuttle-race, or board upon which the shuttle slides, so is the shuttle upon that shelf brought in line with the picker, and may be driven to the corresponding box on the opposite side of the batten. a, a, a represent the drop-box. In Fig. 2908 it

will be seen that the bottom shuttle is on a line with the picker *d*. There are but two pickers, which slide horizontally upon spindles, and are driven by means of a stick and cords *g g*. An additional cord *h h* is provided in order to draw the picker out of the drop-box after the shuttle has been driven; otherwise it would prevent the box from being raised or lowered when required. In Fig. 2907 the dotted lines *D D* show the position of the picker after it has thrown the shuttle out of the box, when the elastic cord *h* withdraws it clear of the drop-box. It is by this simple and effective means that two or more shuttles can be used without difficulty. Each shuttle can be thrown either once or any number of times, and they may be thrown in any order which may be desired.

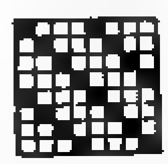
In applying the use of several shuttles to the power-loom, the difficulty to be overcome is far greater than would appear at first sight. So long as the speed of the loom is but slow, the task can be accomplished in many ways and with success; but to drive such looms at the speed exacted from the modern power-loom would destroy them in a very short time. As the speed of the loom has been increased, the more simply its parts are contrived, the more capable it becomes of working at that speed; but to apply several shuttles to a power-loom, so that each shuttle can be used any desired number of picks, and be immediately changed for another shuttle, necessarily gives rise to a considerable amount of complicated motions. To simplify these as much as possible, the box containing the shuttles is applied only to one side of the loom; consequently, when a shuttle is thrown through the shed, it is received into a stationary box on the other side, and it must be returned before another shuttle can be thrown. To throw the shuttles one pick only cannot be accomplished on these looms.

Figured Weaving.—There are various methods of arranging the loom for producing figured or ornamental fabrics, the principal ones of which may be classified as follows: 1. The use of healds in any practicable number, in regular or irregular order, as in weaving satins, twills, spots, or small figures. 2. By forming the healds into groups of two or more divisions, in such a manner that any of the divisions may be brought into action, each division having a distinct and separate control over the whole of the warp, at the same time each warp-thread to pass through one eye or leash only of the healds, as in diaper-weaving. 3. By passing the warp through two separate harnesses, so that each thread of the warp passes through two eyes, both harnesses having a compound control of the warp, as in damask-weaving. There are other kinds of weaving, such as gauze, velvet, etc.; but they are produced by entirely different processes from the above.

2909.

Twills.—In describing plain weaving it has been shown that half the warp-threads are passed through the eyes of one of the heddles and the other half through the eyes of the other heddle. The result of such weaving is threads interlacing each other alternately. In twilled or tweeled cloth the threads, instead of being thus disposed, intersect at certain regular intervals. Thus, in Fig. 2909, the weft-thread *a* passes under every fourth thread of the warp, in such a manner that after it has passed from side to side of the cloth four times it has intersected all the threads of the warp. These intersections, being made in regular and consecutive order, give rise to the diagonal appearance which is known as a "twill." Fig. 2910 shows how this twill is represented on design paper. It will readily be seen that if four heddles are employed, each carrying a separate series of threads, as represented in Fig. 2911, a great variety of patterns may be woven.

2910.



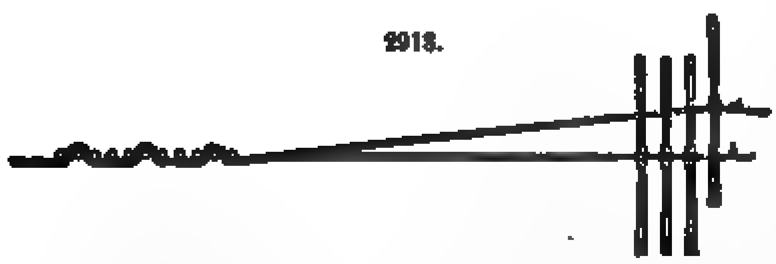
In actual work the number of warp-threads in each inch in width of the cloth may range from 40 to 400 or 500, or several hundred times more than it would be possible to show in a drawing. Therefore, instead of attempting to show several thousands of warp-threads, 16 will be a sufficient number to illustrate the subject. In the hand-loom the heddles are suspended from four levers called *tumblers* or *coupers*, which work on the *top castle* of the loom, as its top framing is named. To the lower laths or shafts of the heddles weights are attached. To the four treadles four long levers or

marches are attached, and from the ends of these marches cords connect them with the tumblers. Now, as each of the heddles is attached to or connected indirectly with one of the treadles, it follows that on pressing upon any of the treadles the corresponding heddle will be raised, and consequently the four threads of the warp will be raised also, and thus a shed will be formed for the passage of the shuttle.

This is clearly shown in Fig. 2911, in which one of the heddles, H^1, is shown raised in the manner mentioned. In the same figure the course of the weft-thread W may be traced, and the various warp-threads under which it passes may be followed to see in which of the heddles each intersection of the weft-thread has been made. Thus the numbers 1, 2, 3, 4 on the weft-threads correspond to the number of the heddle which has been used when the weft was inserted. The lease or cross is shown at N, but the reed has been omitted in the diagram, in order to avoid unnecessary complexity. Fig. 2912 is a plan of Fig. 2911, in which the threads may be more distinctly seen. It will be noticed that D, Fig. 2911, represents, as it would be shown on design paper, the cloth as shown at C, Fig. 2911. A section of Fig. 2911 is shown in Fig. 2913.

2912.

2913.



It will be seen that it is by raising the heddles singly and in consecutive order that a twill, such as shown in Figs. 2909 and 2911, may be woven.

Double-Cloth Weaving.—There is still another system, perhaps the most important in weaving, to be noticed, viz., the method of weaving double cloths. As before stated, it is by this means that the manufacturer can not only make thicker and heavier cloths, but he is enabled to use the materials to the best advantage. Although the illustrations are confined to the use of four heddles only, the principle upon which it depends can be fairly represented.

Fig. 2914 represents a piece of cloth composed of black and white warp-threads placed alternately. At $a\ a$ the weft-thread is shown to pass under the white and then the black threads alternately. At $b\ b$ all the white threads have disappeared, and the black alone are represented; and if these were sufficiently numerous to cover the weft-thread well, the surface of the cloth would appear black. At $c\ c$ all the black threads have disappeared, and the white threads are thrown upon the surface instead. Thus a black or white surface can be woven at pleasure. Fig. 2915 shows a section of the cloth, and

2914.

a a b b c c

2915.

2916.

it will be seen that when the white threads disappeared at $b\ b$, Fig. 2914, they lay unconnected with the cloth or floated on the surface; and in the same manner the black threads float at c when the white threads are being used. In some kinds of figured weaving these floating threads are cut off, as may be noticed in figured shawls; but in such cases the loss cannot be avoided.

Now on comparing Fig. 2916 with Fig. 2914, the surfaces of both are alike; but on comparing their sections, Figs. 2915 and 2917, a great difference appears. When either the white or black threads disappear on one side of the cloth, they are not found floating underneath, but are being woven into another cloth; in fact, two separate pieces of cloth connected at the edges, or selvages,

are being woven, forming a tube. If a few of the threads were at intervals interwoven from one surface to the other, the two cloths would then be bound together, and form one compact piece, and the spaces *a a*, Fig. 2917, would not exist. Again, an entirely different set of weft-threads may be inserted so as to fill the spaces *a a*, to which the upper and lower surfaces of the cloth could be attached without the threads passing entirely through the cloth to the other side. Three varieties of weft may in this manner be used. The central weft-thread is called the wadding, and cannot be observed on either surface of the cloth.

On referring to Fig. 2909, it will be seen that there are two threads at each edge of the cloth which are intersected alternately, as in plain weaving, by the weft-thread. Only two threads are shown, although in practice various numbers are used. If these selvage threads were not inserted, the edges of the cloth would be very irregular, if the weft followed the course of the ordinary warp-threads. This may be understood by referring to Fig. 2911.

Satin-Weaving.—As far as the use of four healds only is concerned, the principle upon which satins, twills, zigzags, and double cloths are woven has been shown. But as four healds are the smallest number that could be used for the purpose, it is necessary to exhibit the use of a greater number of healds, and indicate how they may be employed in the weaving of ordinary satins, etc.

In silk-weaving, as many as 16 leaves and upward are used in making very rich satins. Fig. 2918 represents the order in which the intersections are made, and Fig. 2919 shows the appearance of the face of a 16-leaved satin when magnified. The intersections only occurring once in 16 times, the weft-threads, although they may be of different colors, are scarcely discernible in the face of the cloth. The warp-threads, when very numerous and crowded together, naturally tend to cover over the few intersections, and the threads thereby give that smooth and unintersected appearance by which rich satins are distinguished.

2919.

2918.

Diaper-Weaving.—In this class of weaving two or more divisions or sets of harness may be used. These are so arranged that any of the sets or divisions when used govern and alter the action of the remaining sets. By this means, very extensive designs may be woven for table-cloths, shawls, etc. Fig. 2920 represents a plan of a diaper harness in two divisions only, with the warp and a simple diaper pattern woven.

Damask-Weaving.—In this class of weaving two separate systems of harness are used in the loom, in such a manner that after the warp has been passed through one set, it is passed through the second set, each set of harness having an especial duty to perform, although they both operate upon the same warp-threads. The first harness through which the warp passes is for the purpose of forming the pattern, as it were, on a large scale; and the purpose of the second harness is to break up this pattern into detail and complete the necessary minute intersections. In other words, in the first instance the outline of the pattern is formed, and in the next case that outline is woven in detail, so that each thread is intersected or woven together, as in twill or satin of any desired description.

2920.

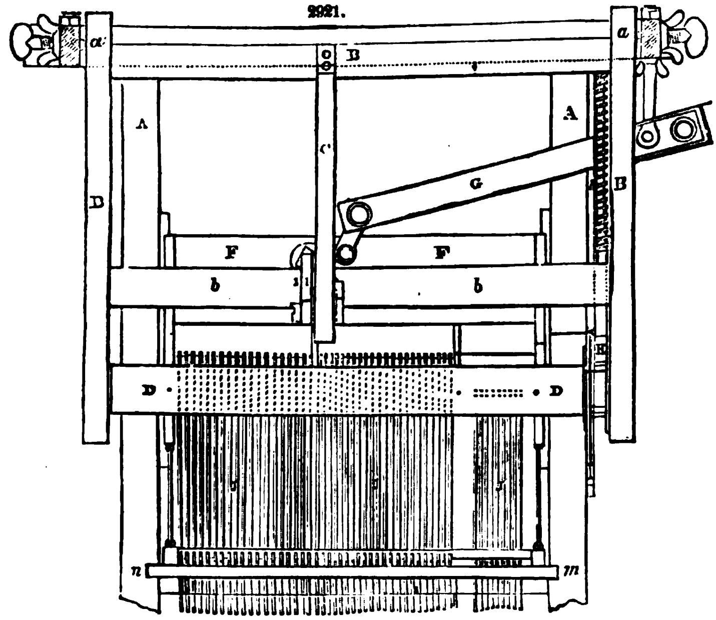
The Jacquard Apparatus.—Up to the invention of this device, the loom consisted of a complicated mass of cords, levers, and pulleys, which had to be compactly united or arranged together to produce the desired pattern or cloth to be woven. Every new design required a fresh arrangement, which often entailed a great amount of labor. In 1725 M. Bonchon made use of "perforated paper pressed by a hand-bar against a row of needles or horizontal wires, so as to push forward those that happened to be opposite the blank spaces, and thus bring loops at the lower extremity of vertical wires in connection with a cone-like rack below. This, being depressed by hand, pulled down the selected wires, and with them the tail-cords to which they were connected." (See "Report on Paris Exhibition," 1867, by Rev. R. Willis.) This contrivance was improved by Vaucanson in 1745. In 1790 it was reinvented by Jacquard of Lyons, who adapted it to practical uses.

The apparatus, which can be attached to almost any kind of loom, is made as follows: A hollow prismatic box extending the width of the fabric has each of its sides perforated in the direction of its length with a number of straight rows of holes, corresponding, as each face is presented to the fabric, accurately to the points of as many rows of metallic bars called needles or spindles. Each of these needles is pressed toward the box by a spiral spring, and each has passing through a loop in its length a lifting-hook, which takes up when lifted its proper thread of the warp. These rows

of lifting-hooks terminate above also in hooks, and an arrangement of lifting-bars is let down after each throw of the shuttle, to engage these upper hooks, raise the lifting-hooks, and with them the warp-threads. The prismatic box has also a reciprocating movement by which at the same moments its sides are brought up to the ends of the needles; and it turns to present a new face at each movement. If all the needles enter the holes of the box, all the lifting-hooks are in position and are engaged by the lifting-bars as they descend, and all the warp-threads are raised. But the weaving of complicated figures, such as those of carpets, tapestries, or shawls, requires that, through a certain cycle of movements of the shuttle, new groups of the warp-threads continually shall be elevated. To determine, then, the groups of threads that shall be raised, a succession of stiff cards, looped together to form an endless chain of any required length, and all of size and form corresponding to those of a side of the perforated box, are made to move successively over the box, one lying flat upon it at each of its movements. Now, the order and groups of threads raised are simply determined by perforating these cards beforehand, and in succession, with groups of holes that shall precisely correspond only to the threads to be lifted for that part of the pattern. When the box now advances upon the needles, those meeting the unperforated portions of the card are forced back, their lifting-rods are moved out of position, and only the threads answering to the needles that enter the holes are raised. With the use of this apparatus, it is only necessary further to arrange properly the succession of colors to appear in the weft, or in both warp and weft.

In Figs. 2921 to 2928 the details of construction are exhibited. Fig. 2921 is a front elevation of this mechanism, supposed to be let down. Fig. 2922 is a cross-section, shown in its highest position. Fig. 2923 is the same section, seen in its lower position. *A* is the fixed part of the frame, supposed

2921.



to form a part of the ordinary loom; there are two uprights of wood, with two cross-bars uniting them at their upper ends, and leaving an interval $x\,y$ between them, to place and work the movable frame *B*, vibrating round two fixed points $a\,a$, placed laterally opposite each other, in the middle of the space $x\,y$, Fig. 2921. *C* is a piece of iron with a peculiar curvature, seen in front, Fig. 2921, and in profile, Figs. 2922 and 2923. It is fixed on one side upon the upper cross-bar of the frame *B*, and on the other to the intermediate cross-bar *b* of the same frame, where it shows an inclined curvilinear space *c*, terminated below by a semicircle. *D* is the box, a square wooden axis, movable upon itself round two iron pivots, fixed into its two ends, which axis occupies the bottom of the movable frame *B*. The four faces of this box are pierced with round, equal, truly-bored holes. The teeth *a*, Fig. 2925, are stuck into each face, and correspond to holes *a*, Fig. 2928, made in the cards which constitute the endless chain for the healds; so that in the successive application of the cards to each face of the box, the holes pierced in one card may always fall opposite to those pierced in the other. The right-hand end of the box, of which a section is shown enlarged in Fig. 2924, carries two square plates of sheet iron *d*, kept parallel to each other and a little apart by four spindles *e*, passed opposite to the corners. This is a kind of lantern, in whose spindles the hooks of the levers $f\,f''$, turning round fixed points $g\,g'$, beyond the right-hand upright *A*, catch hold, either above or below, at the pleasure of the weaver, according as he merely pulls or lets go the cord *z*, during the vibratory movement of the frame *B*. *E* is a piece of wood shaped like a T, the stem of which, prolonged upward, passes freely through the cross-bar *b*, and through the upper cross-bar of the frame *B*, which serve as guides to it. The head of the T-piece being applied successively against the two spindles *e*, placed above in a horizontal position, first by its weight,

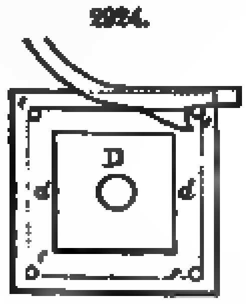
and then by the spiral spring *h*, acting from above downward, keeps the box in its position, while it permits it to turn upon itself in two directions. The name *press* is given to the assemblage of all the pieces which compose the movable frame *B B*. *F* is a cross-bar made to move in a vertical direction by means of the lever *G*, in the notches or grooves *ι*, formed within the fixed uprights *A*. *H* is a piece of bent iron, fixed by one of its ends with a nut and screw upon the cross-bar *F*, out

2922. 2923.

f' f

of the vertical plane of the piece *C*. Its other end carries a friction-roller *J*, which, working in the curvilinear space *c* of the piece *C*, forces this, and consequently the frame *B*, to recede from the perpendicular or to return to it, according as the cross-bar *F* is in the top or bottom of its course, as shown in Figs. 2922 and 2923. At *I* are checks of sheet iron attached on each side to the cross-bar *F*, which serves as a safe to a kind of claw *K*, composed here of eight small metallic bars, seen in section in Figs. 2922 and 2923, and on a larger scale in Fig. 2925 At *J* are upright skewers of iron wire, whose tops, bent down hookwise, naturally place themselves over the little bars *K*. The bottom of these spindles, likewise hooked in the same direction as the upper ones, embraces small wooden bars *l*, whose office is to keep them in their respective places, and to prevent them from twirling round, so that the uppermost hooks may be always directed toward the small metallic bars upon which they impend. To these hooks from below are attached strings, which after having crossed a fixed board *m n*, pierced with corresponding holes for this purpose, proceed next to be attached to the threads of the loops destined to lift the warp-threads. The horizontal spindles or needles *K K* are arranged here in eight several rows, so that each spindle corresponds both horizontally and vertically to each of the holes pierced in the four faces of the box *D*. There are therefore as many of these spindles as there are holes in one of the faces of the box. Fig. 2926 repro-

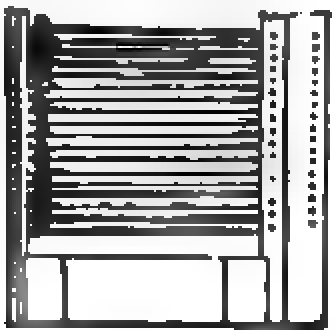
2924. 2925.



sents one of these horizontal spindles. *n* is an eyelet through which the corresponding vertical skewer passes; *o*, another elongated eyelet, through which a small fixed spindle passes to serve as a guide, but which does not hinder it from moving lengthwise, within the limits of the length of the eyelet. Small spiral springs *p* are placed in each hole of the case *q q*, Fig. 2925, serving to bring back to its primitive position every corresponding needle, as soon as it ceases to press upon it. Fig

2927 represents the plan of the upper row of horizontal needles. Fig. 2928 is a fragment of the endless chain, formed with perforated cards, which are made to circulate or travel by the rotation of the shaft *D*. In this movement, each of the perforated cards, whose position, form, and number are

2927.



2928.

determined by the operation of tying up the warp, comes to be applied in succession against the four faces of the box, leaving open the corresponding holes, and covering those upon the face of the box which have no corresponding holes upon the card.

Now let us suppose that the press *B* is let down into the vertical position shown in Fig. 2923; then the card, applied against the left face of the box, leaves at rest or untouched the whole of the horizontal spindles (skewers) whose ends correspond to these holes, but pushes back those which are opposite to the unpierced part of the card; thereby the corresponding upright skewers, 3, 5, 6, and 8, for example, pushed out of the perpendicular, unhook themselves from above the bars of the claw, and remain in their place when this claw comes to be raised by means of the lever *G*; and the skewers 1, 2, 4, and 7, which have remained hooked on, are raised along with the warp-threads attached to them. Then, by the passage across of a shot of the color, as well as a shot of the common weft, and a stroke of the lay after shedding the warp and lowering the press *B*, an element or point in the pattern is completed. The following card, brought round by a quarter revolution of the box, finds all the needles in their first position, and lifts another series of warp-threads; and thus in succession for all the other cards, which compose a complete system of a figured pattern. If some warp-yarns should happen to break without the weaver observing them, or should he mistake his colored shuttle yarns, which would so far disfigure the pattern, he must undo his work. For this purpose he makes use of the lower hooked lever *f'*, the use of which is to make the chain of the card go backward while working the loom as usual, withdrawing at each stroke the shot both of the ground and of the figure. The weaver is more subject to make mistakes, as the figured side of the web is downward, and it is only with the aid of a bit of looking-glass that he takes a peep at his work from time to time. The upper surface exhibits merely loose threads in different points, according as the pattern requires them to lie upon the one side or the other.

Thus it must be evident that such a number of pasteboards are to be provided and mounted as equal the number of throws of the shuttle between the beginning and end of any figure or design which is to be woven; the piercing of each pasteboard individually will depend upon the arrangement of the lifting-rods and their connection with the warp, which is according to the design and option of the workman. Great care must be taken that the holes come exactly opposite to the ends of the needles; for this purpose two large holes are made at the ends of the pasteboards, which fall upon conical points, by which means they are made to register correctly. It will be here seen that, according to the length of the figure, so must be the number of pasteboards, which may be readily displaced so as to remount and produce the figure in a few minutes, or remove it, or replace it, or preserve the figure for future use. The machine, of course, will be understood to consist of many sets of the lifting-rods and needles shown in the diagram, as will be perceived by observing the disposition of the holes in the pasteboard, these holes, in order that they may be accurately distributed, are to be pierced from a gauge, so that not the slightest variation shall take place. To form these card-slips, an ingenious apparatus is employed, by which the proper steel punches required for the piercing of each distinct card are placed in their relative situations preparatory to the operation of piercing, and also by its means a card may be punched with any number of holes, at one operation.

The expense of material and time in preparing the cards for the Jacquard apparatus, which for the heaviest work must be of sheet iron, and for all intricate patterns very numerous, has always constituted the most serious drawback upon the desirableness of that method. Thus an elaborate damask design has required 4,000 cards and 400 needles, at a cost of about $120 and five weeks' labor of a man in setting up; while a single design has been known to require 20,000 cards, at a cost of $600 and time equal to a year's labor of one man. With a view to reduce these expenditures, M. Bonelli constructed the electric loom, in which the cards of the Jacquard apparatus are superseded by an endless band of paper covered with tin foil, intended to serve as an electrical conductor. (See Electric Loom.)

In another improvement of the Jacquard loom, a sheet of prepared paper punched with the proper apertures is substituted for the cards of the old machine, this paper being in form of a continuous band, only three-fourths of an inch wide, so that the weight of the new is to that of the old band as but 1 to 11. The arrangement is also such as permits the 400 spiral springs in connection with the needles in the old machine to be dispensed with. Thus the wear and tear due to the resistance of these is obviated, and fine and light wires are introduced in lieu of the heavy ones previously employed. Various additions have also been made to the Jacquard loom by Barlow, Taylor, Martin, and others; and an ingenious application of it to the positive-motion loom to adapt the latter for weaving corsets will be found described under Loom, Power.

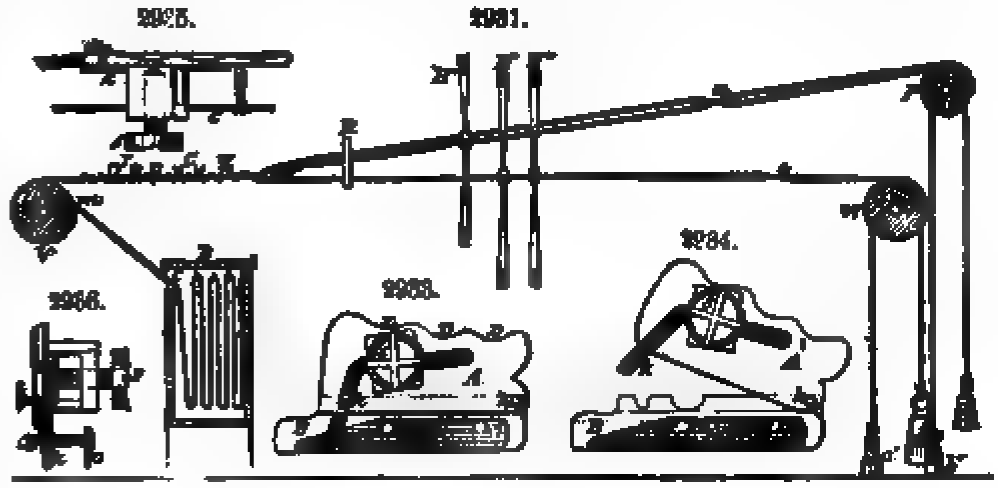
Ribbon-Weaving.—The frames of the most improved ribbon-looms of the present day are still arranged upon the plan of the old Dutch engine or swivel loom. The shuttles are, however, driven by the wheel and rack. The chief improvements in the loom have been the application of the Jacquard machine, and the employment of several tiers of shuttles for using various colors of weft. Figs. 2929 and 2930 show the method of throwing the shuttles or swivels by means of the rack-and-wheel motion. The shuttles *s s* have a small rack inserted, and they are geared in the star-wheels *w w*. The wheels are worked by the rack *R*, and as this rack works all the wheels by its alternate motion, the shuttles are thrown from side to side of the openings through the warp.

2929. 2930.

Pile-Weaving.—This class of weaving includes velvets, Brussels carpets, fustians, etc. It consists in the formation of loops on the surface of the cloth, and if the loops are cut through they form a brush-like surface to the cloth known as velvet. If the loops are left uncut, similar to the loops on Brussels carpets, then it is known as terry velvet. The loops may be formed either by means of the warp-threads or the weft-threads, and they are called the pile-threads. The richest description of velvet made (with the exception of Dutch, Genoese, and specially made velvets) is known as "collar velvet" for gentlemen's coats. The pile-threads are of silk, but the weft is often of cotton, and velvets so woven are said to have cotton backs. Cotton makes the body of the cloth firmer and more suitable for the purpose than silk, so that the inferior material is not used on the score of economy alone.

Fig. 2931 represents a section of a velvet-loom, showing all the working parts necessary, but omitting the framing. *W* is the ordinary warp-beam supplying the threads for the body of the cloth; *P* is the "pole" (corruption of pile) or the pile-beam which contains the pile-threads; *V* is the cloth-beam, showing that it has made three-quarters of a revolution; and *B* is a closed box to contain the velvet as it is unwound from the beam. At *T* will be seen loops rising from the surface of the cloth, and at *C* the loops are shown cut through at their upper surface. These loops are made by inserting thin wires into the shed, which are beaten up with the cloth similar to ordinary weft-threads. One of these wires is shown thus woven in the cloth at *w*, and at w^1 another wire is being inserted. Now between each insertion of the wires three shoots of weft are thrown into the cloth, and well beaten together; otherwise the pile-threads after they were cut would draw out. Fig. 2932 shows a plan of Fig. 2931, and the same letters and numbers refer to each. In the plan the wire w^1 is shown placed in the shed of the warp, and will be driven up by the reed *R* in the same manner as the wire *w* has been. When both wires have been firmly bound into the cloth by the weft-threads, the first one is cut out by means of a knife fixed into a frame and called a "trevet," and it is again inserted. Thus only two wires are used, and they are cut out alternately by means of the trevet. The instrument is well suited for the purpose, and when it is considered that the wires are inserted from 50 to 60 times, and upward, per inch in length of velvet woven, and three times that number of weft-threads, it will be evident that great exactness in the operation is necessary, as the slightest error or carelessness would cut the warp-threads out of the loom—a circumstance by no means unknown to most velvet-weavers. The wires, which are made with a fine groove for the point of the knife to enter, are very truly made, and the blade of the trevet must be "as right as a trevet"—hence the well-known simile—or such beautiful work as velvet could not be produced. Figs. 2933 to 2936 show the trevet. The knife *k* is fixed into a frame *A*. This frame is hinged to another frame *B* at the point *h*, so that the weaver can open and sharpen the knife easily. The knife is held firmly by the screw *s*, and at the back of the frame a small adjusting screw *e* is placed to regulate the distance of the knife from the steel frame *B* against which it is placed. The frame *A* is of brass, but all the rest is of steel. The indentations *z z z* are for the fingers to fit in, a requisite precaution to insure accurate hold of the instrument. The use of the trevet is shown in the enlarged sketch, Fig. 2937, in which the knife-edge is seen entering the wire *w*. *B* and *C* are the bottom portions of the trevet, and rest upon the warp and cloth as shown. The trevet is held in the right hand, and drawn from left to right. It is pressed

2935. 2931.



2932.

against the flat side of the outside wire w^1, which forms the guide or fence, and the knife is regulated to fall into the groove of the inside wire w. When upward of 60 insertions of the wires per inch are made, an idea of the perfection of workmanship required for the purpose may be realized. About six times in length of the pile-threads are used to what are required for the "back," which, of course, arises from the formation of the loops. Much less strain is also put upon the pile-threads by the use of smaller weights, as shown at b and b^1.

After leaving the beam the velvet is hung up by means of pin-hooks in the box B, Fig. 2931, which keeps it free from injury. The warp- and pile-threads may be traced in the figures as well as the weft. The heddles shown at H^1 and H^2 work the ground- or warp-threads by raising each half of the threads alternately as in plain weaving. The heddle H^3 raises the pile-threads at every fourth change. Singular as it may appear, when the work is taken from the loom the weaver places it upon a table, and by means of a sharp common razor literally shaves or mows the whole surface of the pile in order to remove any stray filaments of extra length and to improve the face of the cloth. Fig. 2938 shows a section of the velvet through the line of warp-threads, in which $s\,s$ is the weft, $w\,w$ the ground- or warp-threads, and $p\,p$ the pile. Fig. 2937 is a section at the side of the cloth, and the letters refer to the same parts. In these figures the actual formation of the cloth is represented, excepting that the pile-threads are usually made thicker or doubled.

Brussels and other pile carpets are made upon the same principle as the velvet above described, but generally the pile is not cut; consequently round wires are used instead of grooved ones, and they are drawn out from the side of the cloth. There are two descriptions of carpets, one in which the pile-threads have had the pattern printed upon them previous to weaving, and the other in which the threads are used dyed in separate colors. The first kind is known as tapestry carpets, and form a comparatively simple and cheap manufacture, when compared to Brussels carpets. Let Fig. 2939 represent the warp- and pile-threads, with the pattern printed upon the pile-threads. The pile-threads are marked $p\,p$ and the ground-threads $w\,w$, these lying between and under the pile-threads. About five of these warp- or ground-threads are used to each strand of the pile, which may be seen in section in Fig. 2940. Now when the threads are woven together the pile is contracted to nearly one-third of its length in consequence of the loops, and the distorted figure, as printed, becomes of the intended

2938. 2937. 2939.

2941.

2942.  2943.

proportions. Thus Fig. 2939 becomes, when woven, Fig. 2941. A section of the cloth is shown in Fig. 2942, and in all the figures the same letters refer to the same parts. The threads $e\,e$ do not intersect with the weft, but merely lie between the warp-threads $w\,w$, and form a bed or ground for the pile to rest upon. The wires used are generally six or more in number; for if only two were used the loops would scarcely resist the strain of drawing the wire, the greater number causing greater firmness to the cloth to resist the strain.

Brussels carpet is a very different affair. A great variety of threads of different colors are required, and they are selected by the action of the Jacquard machine to form the pattern. They are wound upon separate bobbins, for each color is used in various lengths. Fig. 2943 represents a section of a Brussels carpet. The threads $a\,a$ are the warp threads, and $s\,s$ the weft. Where there was only one thread in the tapestry carpet there are five in the Brussels; thus the pile-threads are shown at $w\,w$, and as the various colors are required they are drawn to the surface to form the loops, while four-fifths remain in the body of the cloth. The great number of pile-threads, and their being of wool and not of hemp, as the warp and weft are, cause the Brussels carpet to be much thicker, the colors brighter, and altogether a superior carpet to the less costly tapestry, as the difference in price attests.

Many kinds of carpets and rugs are woven on the systems above described, but have the pile cut as in cut-velvet weaving, such as Axminster and Wilton carpets.

The foregoing article is abridged from a valuable series of practical papers on weaving in *Engineering*, vols. xvii., xviii., and xix. See also "The History and Principles of Weaving," Barlow, London and New York, 1879.

LOOMS, POWER. Power-looms may be divided into four classes:

1. The plain-cloth loom, or plain loom as it is more commonly termed, in which each alternate thread of the warp is regularly raised and depressed in succession, while the weft is carried across by the shuttle at each such motion of the warp, and in which the warp-threads receive their motion from a pair of cams on the main shaft of the loom.

2. The twill looms, in which three or more cams are used, operating successively on a portion of the warp, while the weft is thrown in at the motion of each cam, in such a manner as to produce a surface marked by diagonal lines, produced by the intersection of the warp and weft.

3. The multi-harness, tappet, or chain loom, in which a number of harnesses are used, as high in

some cases as 40, which harnesses are operated by movable tappets, or adjustable projections on a wheel or chain, so as to lift them in an irregular succession, but in one which is limited by their

2944.

number. This loom is used for weaving fancy cassimeres, and other goods which have an irregularly figured surface, sometimes of several colors, but often only of one; and the pattern or figure is also regulated by the order in which the warp-threads are drawn through the eyes of the harness.

2945.

4. The Jacquard loom, in which each thread of the warp has an independent harness or *mail* of its own, and the operation of which is fully described under LOOMS, CONSTRUCTION AND USE OF.

In connection with all these looms, however, may be used the double shuttle-box, such as is applied for weaving checks and plaids, or, as in the carpet-loom, is extended to carry a number of shuttles, holding different colors.

The essential parts of all power-looms are the frame, the lathe, the shuttle motion, the harness or heddle motion, the take-up motion, the let-off motion, the weft or stop motion, the crank and cam shafts, the warp and cloth beams, the heddles, the reed, the temples, and the shuttle and shuttle-box.

Power-looms are also classified according to the manner in which their shuttles are operated, and in this respect form three distinct classes:

1. The picking-stick loom. In this loom the shuttle is made from apple-wood, jointed at both ends and shod with iron points. A slot is cut through it running nearly its whole length, in which is a spindle which carries the *cop* or weft.

2. The positive-motion loom. In this loom the shuttle is drawn through the web by the continu

ous contact of its driver. Hence the width of the web and the number of shuttles which it is possible to carry across simultaneously are unlimited.

3. The rack-and-pinion loom. In this loom the shuttle is pushed from one side of the web and drawn out at the other, through its engagement with pinions driven by racks at each side of the web. The shuttle is made of box-wood, and is shaped like a quarter moon, with an opening of the same shape to receive the weft. In length it is three times the width of the web, and hence its use is limited to very narrow weaving. The general operation of the rack-and-pinion loom is described under "Ribbon-Weaving" in LOOMS, CONSTRUCTION AND USE OF.

PICKING-STICK PLAIN LOOMS.—Fig. 2944 represents a light or fast-running plain loom built by the Whitin Machine Works in Whitinsville, Mass. The loom is shown from the rear, and exhibits, besides its own especial construction, many of the essential portions common to all looms. At *A* are the side frames which form the gable-ends. These are tied together front and back by girts. In front is the breast-rail over which the fabric passes, and in rear is the back rail. This last is termed the back rail when stationary or the *whip-roll* when it is movable; it serves to support the web between the warp-beam *C* and the harness (not shown). *D* is the arch which extends from gable to gable, and supports the harness.

The following are the principal moving parts of this loom: The lay or lathe, *E*, supports the shuttle in its passage through the web and carries the reed. The lathe is supported by uprights *F*, called the swords, which have a fulcrum in the gable-ends near the floor. The lathe is vibrated by the crank-shaft *G*, to which it is connected by means of pitmans. Immediately under the crank-shaft is the cam-shaft *H*. The cams on this act upon treadles which move the harness. It will be

noted that these shafts are geared together. At each end of the lay are the shuttle-boxes *I*. These receive the shuttle as it is driven from side to side by the picker-staffs *K*. These staffs rock upon shoes at their lower ends, and thus the extremities are given a parallel motion. They are actuated through picker-cams secured on the cam-shaft and placed just inside the gable-ends, which act on suitable levers. These levers are connected to the picker-staffs by straps, and springs are arranged to keep each staff in the extreme end of its shuttle-box when it is not engaged by the picker-cams. Inside the shuttle-boxes "swells" are usually hinged. When the shuttle enters the box, it presses these circles outward, and thus moves a projecting rod so that the latter is prevented from acting on the belt-shipper. In case the shuttle does not enter its box, this action does not take place, and the loom is automatically stopped.

The loom represented in Fig. 2945 is designed for light goods, print-cloth, etc. The pulleys run from 150 to 175 revolutions per minute. The engraving illustrates a 30-inch plain loom built by the Mason Machine Works, of Taunton, Mass. This loom is also suited to the weaving of print-cloths.

Picking-Stick Multi-Harness Looms.—*The Crompton Loom*, shown in Fig. 2946, is an excellent and well-known type of the multi-harness loom, intermediate between the plain or twill loom and the Jacquard, in which a definite number of harnesses is used, within the scope of which the pattern must be repeated. This is done by the action of the pattern-chain shown at *A*. This consists of a pair of endless chains, connected by rods, on which rods are slipped movable rollers as shown, these rollers being kept in their proper places by thin collars, which are also slipped on the rods, and fill up all the space on them not occupied by the rollers. This chain passes around a carrier-roll shown at *D*, which is rotated the length of one link of the chain by a ratchet motion, connected with a crank-disk on the main shaft of the loom, at each revolution of the shaft or blow of the lathe; and passing between this carrier-roll and the harness-levers *B*, the latter, which are pivoted in the centre, are vibrated to the right and left by the chain-rollers, according to their interposition or non-interposition between the carrier-roll and the bearing points of the levers. The cords *E* pass from the top and bottom of these levers to the harnesses *C*, around the pulleys *F*, and thus raise and depress these harnesses by the lateral motion of the levers. A similar chain passing around the roller *G* operates the levers *A*, and by the chain *I* passing over the roller *J* raises or lowers the shuttle-box *K*, so as to bring the opening of either box desired level with the race of the lathe. The length or "repeat" of the pattern is of course governed by the number of links in the chain, which can be "made up" of any desired length. Twenty-four-harness frames form the limit which can well be applied to a loom of ordinary width of shed; but by applying another set of levers to the other end of the loom, with the harness threads of sufficient length to permit of the operation of their frames above and below the space occupied by the ordinary frames, and placing the harnesses in the loom alternately, so that the eyes of the long set can pass up and down between the frames of the short set, 48 harnesses can be operated.

Fig. 2947 represents a satinet loom by the same maker as the preceding, which is designed for heavy goods, such as satins, twills, jeans, etc. It has four boxes at one end, and an endless chain governs and moves the heddle-levers, and can be readily changed to any pattern without the aid of cams. The loom is of the open-shed type, and its speed is 120 picks per minute

Silk-Weaving Loom.—A new and very ingenious loom has been lately introduced for weaving silk fabrics. In this loom, Fig. 2948, the picker-staff *A*, which receives its motion from the crank-disk *B*, carries an eye-pointed needle, which, receiving the weft from the bobbin *C*, passes it through the open shed of the warp, where the loop of weft which is formed by it is caught and held by a selvage thread, which is passed through the loop by a shuttle motion similar to that on a sewing machine. The advantages claimed for this loom are: much higher speed, from the light weight of the needle and weft to be moved at each pick, as compared with any shuttle; less chafing and abrasion of the warp, from the very slight opening required for the shed; and the saving of loss of time in changing shuttles, the weft being fed from a long cop holding many thousand yards. The harness motion is

operated by cams at *D*, and is of course capable of the variations which can be given to any loom, the novelty being in the application of the weft motion.

THE LYALL POSITIVE-MOTION LOOM, manufactured by Messrs. J. & W. Lyall of New York, is a recent and very valuable invention, and is remarkable for the great scope of its usefulness. It is applicable either to the weaving of very wide and heavy fabrics, such as jute canvas for the foundation of floor oil-cloths, or of the finest and most delicate yarns.

2948.

The advantages embodied are: First, the abolition of the picking-sticks; second, a positive motion to the shuttle from any point in its course; third, the unlimited width of the fabric which may be woven; fourth, the unlimited variety of fabrics which may be produced, from the finest silk to the heaviest carpet, from jute oil-cloth foundation to exquisite woven embroideries; fifth, the almost total absence of wear, through the small motion of the reed, which thus wears but little on the warps, through the small opening of the heddles, which thus offer less strain on the same, through the absence of friction of the shuttle on the yarns, and the non-subjection of the weft to sudden pull on starting; and sixth, the extremely small amount of power required to operate the looms. The shuttle motion, which is the essential feature of the invention, will be understood by referring to Fig. 2949, where the shuttle is shown resting on its carriage *o*. Motion is given to the carriage and through it to the shuttle by means of a stout band *u*, which passes over grooved pulleys fixed to the ends of the lay and communicating with a single large pulley underneath the loom, to which, by special mechanism hereafter to be described, the proper movement is imparted. The wheels 2 of the carriage are pivoted to the ends of short horizontal arms; the wheels 3 are simply journaled in the carriage. The weight of the latter, therefore, rests on the pivots of wheels 3; and as these rest on the tops of wheels 2, it follows that they must receive a counter-motion in the direction of the arrows marked on them, exactly equal to the motion of wheels 2, which is likewise equal to the

2949.

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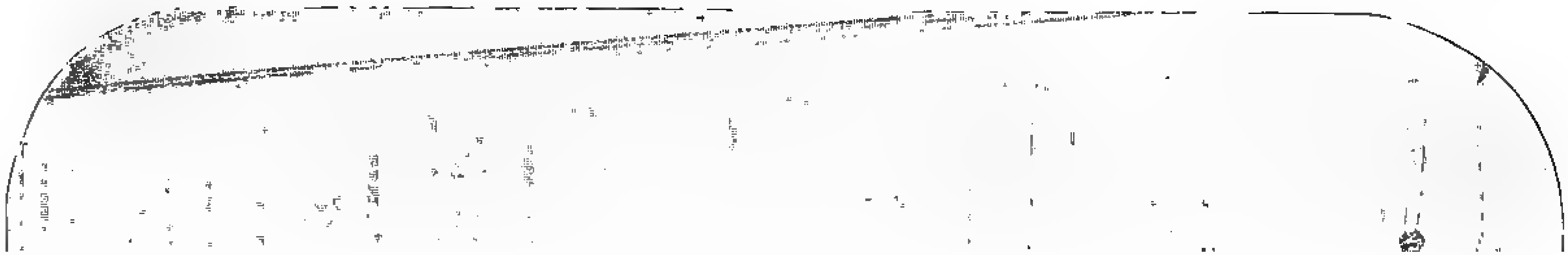
motion of the carriage along the raceway *l*. Now suppose a sheet of parallel threads to be stretched above this carriage and beneath the shuttle *p*. The only points where these threads will be in contact with carriage and shuttle are obviously between the wheels 3 of the former and wheels 4 of the latter. If we move the carriage so that the wheels 2 revolve to the left, wheels 3 will rotate to the right; and supposing the shuttle removed, it is clear that, while the threads are successively raised as wheels 3 pass under them, the rotation of said wheels precludes any lateral movement on their part. It is easy to see that the laying of the shuttle in place above the carriage will in no wise affect

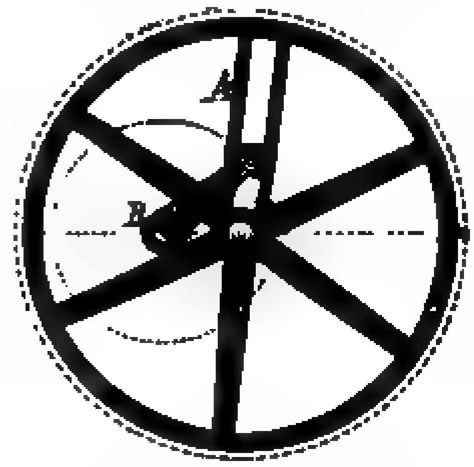


THE LYALL LOOM.

this result, because the wheels 3 rotate the wheels 4 at precisely the same speed; so that the successive threads, for the inappreciable instant of time during which they are between shuttle and carriage, sustain no disarrangement from their normal position beyond the very slight elevation, a small fraction of an inch, caused by wheels 3. This clearly imposes no strain, while a moment's consideration of the mechanics of the device will show that friction on the threads is practically

2950.

2951.



nothing, being applied at the mere line formed at the place of contact of two rolling bodies, and this never twice at the same points considered in horizontal succession from thread to thread, because the sheds are constantly alternating and constantly being moved bodily away as the weaving progresses. The wheels 5 do not engage with the wheels 4, but roll along the under surface of a beveled rail, holding the shuttle down to its work. The shuttle is dovetail in section, and, when in place with its carriage, can only be removed by drawing it out at the end of the lay.

The loom mechanism will be understood from Figs. 2950 and 2951. It is necessary in many cases to produce a dwell or period of rest, either in the shuttle or the lay. In the one case the shuttle stops sufficiently long at the end of its run to allow of the lay being beaten; in the other, the lay delays its beat sufficiently for the shuttle to make its journey. The dwell in the lay is necessary in making heavy goods. In all cases it is a great desideratum to have the motion of the shuttle swiftest midway in its course, and gentle at the ends; and one way in which this is accomplished is shown in Fig. 2950, where *A* is a crank-disk, from which motion is imparted by a connecting-rod *B* to a sliding block in the slotted vibrating arm *C*. *D* is a link attached to the sliding block and pivoted to the frame. Arm *C* carries, as shown, the wheel, actuates the shuttle-band, and is itself rotated by a rack-and pinion device, clearly represented. When the crank-disk starts from the position exhibited (the shuttle being at the end of the race), the sliding block is at the upper end of the slot in arm *C*. Hence the arm, and consequently the shuttle, is given very slow motion. But as one end of the connecting-rod is carried up the disk, its other end causes the sliding block to descend to the arm, the wheel on the outer extremity of which, therefore, constantly receives an accelerated motion, which is most rapid when the shuttle is midway in its course, and gradually in the same manner decreases until the pick is made. The shuttle is never returned until the lay is got home; so that, no matter what the position of the shuttle is to the race when the loom is stopped, on starting again the first thing done is to draw it out of the way of the lay.

2952.

Dwell in the lay, an obvious necessity when the shuttle, in weaving wide fabrics, has to travel a very long distance, is obtained by the device represented in Fig. 2951. *A* is a slotted pulley-wheel, in the slot of which is a sliding block, to which is attached the crank of the shaft *B*, which imparts motion to the lay. The crank-wrist is eccentric to the pulley; and as the latter revolves, it moves radially in the slot. Consequently, when nearest the centre it imparts an extremely slow

or no motion to the shaft *B*, and a quick movement when it has traveled out toward the circumference.

Fig. 2952 represents the plain positive-motion loom. In a full-page engraving is shown the wide loom exhibited at the Centennial Exposition. This great machine was used for weaving floor-cloth, making a fabric 8 yards in width and 40 yards in length in 10 hours, or 320 yards per day. The shuttle traveled 31 feet at every run, and moved 35 times per minute.

Another form of positive-motion loom, Fig. 2953, weaves four webs of seamless bags, crash, canvas, etc., up to 26 inches wide, with one mechanism. There are four shuttles connected by rods in the single raceway; and they are caused to travel so that each, in passing to one side or the other, fills the place previously occupied by its neighbor. The bottom of the bag is closed in the loom, so that as the bags are woven it is merely necessary to cut them apart. The machine travels at the rate of about 120 picks per hour. An important advantage of this loom is shown by the fact that by actual test it has been found to produce more material in a given time than can four separate looms, each making one bag. The reason of this is stated to be that when four looms are used, if

2953.

an accident happens to one of them, the entire attention of the operative in charge of the four is given to remedying it, and hence the other three looms are allowed to run on unattended, the lack of care resulting very probably in other accidents in them. The consequence is that the aggregate work of the four looms rarely exceeds the continuous work of two machines. In the four-beam loom here represented, when an accident happens, the whole machine stops, and thus no further damage can be produced. One girl can attend two of these looms, equal to eight ordinary looms.

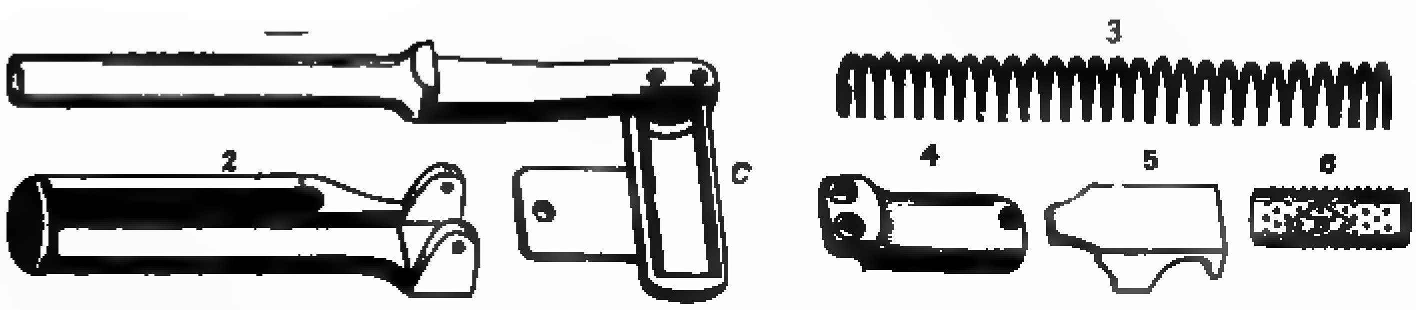
The corset-loom, Fig. 2954, is a combination of the positive-motion power-loom with the Jacquard apparatus. Four webs of corset are woven at once, in perfect form, all precisely similar, and yet possessing every gore, every gusset, every welt formerly laboriously put in by hand-work. Five corsets per day was the extent of the labor of the German weaver; this wonderful invention makes 84 in infinitely superior manner in the same time. The Jacquard cards govern the quantity of warp to be kept in action, so that, when for instance the parts which fit about the protruding portions of the body are to be made, only a certain portion of the warp is kept in play, and through this only the weft passes. As the shuttle then does not pass through the whole warp, but over a portion of it, it would necessarily seem that a slack loop of weft, corresponding to that portion in length, would be

left. This is provided for by a let-off device in the shuttle, so that the thread, passing to and fro (after leaving the bobbin) several times between extended leaf-springs, is always held taut, and thus only the exact amount required for the pick is allowed to escape.

THE LOOM TEMPLE.—An important accessory to the loom is the "temple," which serves the purpose of holding the cloth extended to the full width of the reed during the operation of weaving. The most common form of it is represented in Fig. 2955. A pair of temples are used, one at each side of the cloth. At 6 is the roller, made of wood, and set with fine steel teeth, which revolves in the cup c of the temple-bar 1. This bar, with its spring 3, plays longitudinally in the stand 2, which is bolted to the breast-beam of the loom at a. The roll is covered by the top c, which just clears the point of the teeth, and the bar is held on the stand by the cap 5. The spring 3 holds the temple in position, yet permits it to yield, so as to avoid fracture should the shuttle get caught between it and the lathe of the loom.

LET-OFF AND TAKE-UP MOTIONS.—The "let-off" is the device whereby the yarn is allowed to unwind from the warp-beam at such a rate as shall be required by the weaving process. This rate depends upon the rate of the picks, the sizes of the warp- and weft-threads, and the compactness with which the material is beaten up by the lay. The "take-up" is the winding on to the cloth-beam of the completed web, and this proceeds coincidently with the let-off from the warp-beam. Regularity of let-off is secured by making the rate of surface motion of the warp-beam depend upon the tension of the yarn; and the rate of revolution of the beam to secure equal speed of let-off will become rapid as the bulk of yarn diminishes upon the roller.

2955.



2956.

Let-offs may be either positive or frictional. In the first case they are so made as to let off a given amount of yarn and no more for each swing of the batten. A frictional let-off gives off all the yarn that the take-up will take from it. The take-up may be positive, requiring a given amount of yarn, or it may be conservative, taking all that the let-off will allow it to have. It is obvious that there cannot be both a positive let-off and a positive take-up simultaneously, because the weft-thread is never of uniform size; and not only would this have to be compensated for, but allowance would also have to be made

for the shortening of the warp due to its interlacing with the weft. The nearest approach to this is the positive take-up and frictional let-off; or there may be a positive let-off and a conservative take-up which maintains a constant pull. The relative advantages of these two systems depend somewhat on the fabric woven; but generally, for fine sheeting especially, a positive let-off is preferred, as producing a more uniform fabric.

An example of a frictional let-off is given in Fig. 2956. The platform *A* is held against the yarn by the spring *B*, which also is connected to the ends of the pivoted levers *C*. On the other extremities of these levers are brake-straps passing over wheels on the ends of the yarn-beam. As the yarn diminishes in diameter on the beam, the platform *A* rises. The strain of the spring on the levers, and consequently the pressure on the brake-straps, is thus relaxed, and the yarn is allowed to unwind more rapidly.

Positive take-ups are generally simply pawl-and-ratchet mechanism, there being two pawls, one to hold and the other to push a ratchet-wheel connecting with the cloth-beam by gearing.

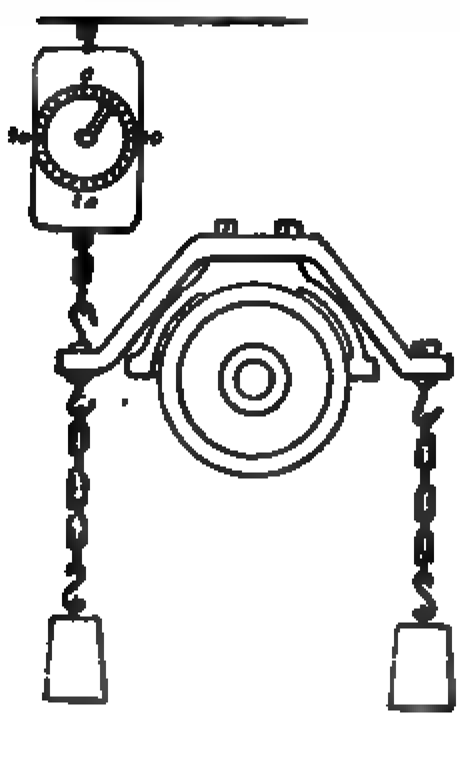
LOUCHETTE. See Dredging.

LUBRICANTS. The table in the article Friction, pages 851 and 852, Vol. I., shows the change in the coefficient of friction due to the use of different lubricants. A lubricant is supposed to produce its effect by filling up the depressions and spaces between the ridges that exist in all bodies, however smooth, and thus converting the friction between rough and unyielding surfaces into friction between smoother bodies. In certain cases, where a bearing is subjected to great pressure, it is made to revolve on water or oil forced under it by hydraulic pressure. Such a bearing, which largely reduces the friction and wear, is illustrated in the article Pumps and Pumping Engines.

2957.

Many inventors, reasoning from the supposed action of lubricants, as explained above, have endeavored to apply some solid material which shall act in the same manner as a fluid lubricant, rendering the rubbing surfaces smoother and less liable to wear. One of the most successful materials that have yet been produced is metaline, the invention of Dr. Stuart Gwynn. Practical experiments, extending over a number of years, seem to show conclusively that there are many places in which this material can be used, taking the place of oil completely. Metaline is composed of two or more alloys, usually with an amalgam to cement the mass together. The alloys are separately reduced to powder, mixed, pressed repeatedly, and abraded after each operation; and are finally compressed to the required form under

2958.



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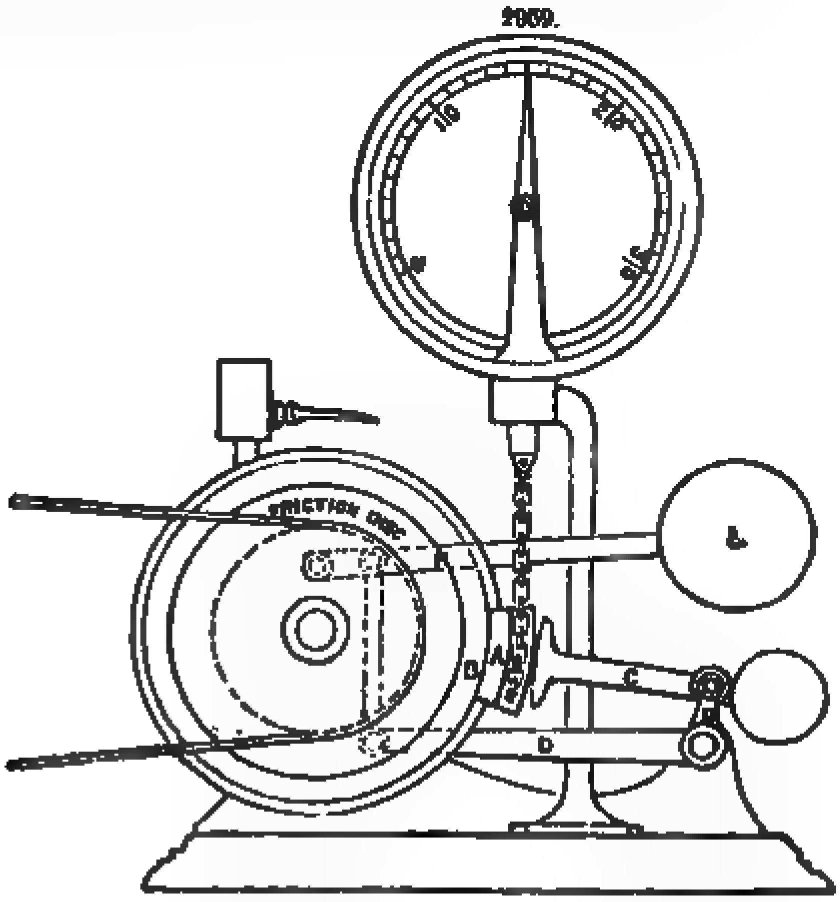


pressures varying from 60 to 100 tons per square inch. Metaline is ordinarily finished in the form of small cylinders, though it is also made in other shapes for special purposes. Fig. 2957 will give a good idea of the manner of using metaline in ordinary journal-boxes. A number of holes are bored in the box, breaking joints, so that no straight line can be drawn in any direction without intersecting some of the holes; all the holes are then filled with the cylindrical blocks of metaline,

and the surface is dressed off smooth. Very small boxes are recessed, and the metaline is forced in, precisely as in the case of a babbitted box. Solid blocks of metaline are also used for small end-bearings, with sections having the form of Schiele's curve described under FRICTION, or of other suitable shapes. Metaline bearings have been used with notable success on loose pulleys, and metaline has been combined with suitable material to form a self-lubricating packing.

The value of a lubricant cannot be determined by simple inspection, and it is only by a series of careful tests that its relative standing in comparison with other lubricants can be fixed. Numerous testing machines have been devised for determining the value of lubricants. A simple one used by R. D. Napier, and described in a paper read before the Philosophical Society of Glasgow in 1875, is shown in Fig. 2958. A pulley was fixed on a lathe-mandrel, and covered with a half bush, which was loaded equally on each side to any desired extent. When the pulley revolved, the tendency of the bush to revolve also was measured by a spring-balance, and the coefficient of friction was determined by the formula $\frac{p}{W-p} \times \frac{R}{r}$; in which expression W is the weight resting on the pulley, including the two loading weights and the half bush; p is the reading of the spring-balance; R is the distance from the centre of the mandrel to the point where the spring-balance is attached; and r is the radius of the friction-wheel. A summary of the experiments made with this machine is contained in *The Engineer* for Feb. 26, 1875.

Fig. 2959 is an elevation of a more delicate instrument used by Mr. Napier. A block A, connected by a chain with the spring-balance, is pressed against the friction-disk by a balanced lever C, which is a segment of a roller, and is pivoted on the short arm of a bent lever $D\ D$. The long arm of this lever is linked with a lever F, the latter having a sliding weight L for the purpose of varying the pressure of the block A on the friction-disk.

Many oil-testing machines are fitted with thermometers for indicating the rise of temperature, and counters for registering the number of revolutions. An elaborate machine, belonging to the Lake Shore and Michigan Southern Railroad Company, is illustrated and described in the *Railroad Gazette* for June 15, 1877. The following table gives the results of some tests made with this apparatus:

Value of different Lubricants, as determined by Tests with Machine on Lake Shore and Michigan Southern Railroad, under the direction of the Purchasing Agent and Master Car-builder, 50 drops of Oil used in each Test, continued until the Temperature of the Oil had changed from 60° to 200° F.

DESCRIPTION OF OIL.	Cost per Gallon.	Number of Tests made and averaged.	Average Duration of Run, in Minutes.	Average Number of Revolutions.	Cost per 10,000 Revolutions, in Fractions of a Dollar.
Castor oil	$1.25	2	28	12,946	.00078
Paraffine, 25°	.28	6	24	11,685	.00019
Mecca oil	.45	2	21	9,982	.00086
Manufactured oil, A	.85	2	19	9,658	.00029
" " B	.90	18	19	9,864	.00077
" " C	.25	2	19	9,287	.00021
Neatsfoot oil	.65	4	17	8,277	.00068
West Virginia (natural)	.20	2	18	7,915	.00026
Sperm	1.75	6	17	7,912	.00179
Tallow	.70	4	17	7,794	.00078
No. 1 Lard	.70	8	16	7,877	.00078
Manufactured, D	.25	2	15	6,999	.00029
" E	.85	12	14	6,798	.00101
" F	.90	2	13	6,121	.00026
West Virginia (reduced)	.20	2	10	4,770	.00088
Grafton oil (treated)	.20	2	10	4 215	.00088

Tests of this character are of course far from complete, since it by no means follows that because one oil will make more revolutions than another under a certain pressure, in having its temperature elevated a given amount, it is in all respects the best. Perhaps, by changing the pressure or the speed of revolution, the result might be reversed: one oil, after remaining on the journal for some time, might become thick or decomposed, and lose its value as a lubricant; or the oil that seemed the best might contain impurities that would be injurious to the metals with which it came in contact. It will be seen, then, that an oil-test, to be complete, involves a variety of steps, which can only be followed by an expert. Such tests as those detailed in the preceding table, however, are of considerable value.

Another very simple test of the relative permanent fluidity of different lubricating oils, an invention of Mr. Nasmyth's, consists of a plate of iron 4 inches wide by 6 feet long, on the upper surface of which six equal-sized grooves are planed. This plate is placed in an inclining position, say 1 inch in 6 feet. The mode of using it is as follows: Suppose we have six varieties of oil to test, and we are desirous to know which of them will for the longest time retain its fluidity when in contact with iron and exposed to the action of the air; all we have to do is to pour out *simultaneously* at the upper end of each inclined groove an equal quantity of each of the oils under examination. This is very conveniently and correctly done by means of a row of small brass tubes. The six oils then make a fair start on their race down hill; some get ahead the first day, and some keep ahead the second and third day, but on the fourth or fifth day the truth begins to come out; the bad oils, whatever good progress they have made at the outset, come soon to a standstill by their gradual coagulation, while the good oil holds on its course; and at the end of eight or ten days there is no doubt left as to which is the best; it speaks for itself, having distanced its competitors by a long way. Linseed oil, which makes capital progress *the first day*, is set fast after having traveled 18

inches, while second-class sperm beats first-class sperm by 14 inches in nine days, having traversed in that time 5 feet 8 inches down the hill. The following table will show the state of the oil-race after a nine days' run:

Results of Oil-Test.

DESCRIPTION OF OIL.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Best sperm oil....	2 8¼	4 2	4 6¼	4 6	4 6	4 6	4 6½	Stat.	
Common sperm oil......	1 7	3 9	4 6¼	4 11	5 1¼	5 4	5 6¾	5 7½	5 8
Gallipoli oil....	0 10½	1 2½	1 6	1 6¾	1 7¼	1 8¼	1 9	1 9¼	1 9½
Lard oil	0 10½	0 11¼	0 10¾	0 11¼	0 11¾	Stat.			
Rape oil..................	1 3¼	1 6½	1 7	1 7¼	1 7¼	1 7¼	1 7¼	1 7½	Stat.
Linseed oil.	1 5¼	1 6	1 6¾	1 6¼	1 6¼	1 6¼	1 6¼	Stat.	

Many interesting particulars relating to tests of lubricants, with descriptions of the principal oil-testing machines in use to-day, were given by Prof. Thurston in a lecture delivered before the Master Car-Builders' Association, Dec. 20, 1877, a good abstract of which may be found in the *Railroad Gazette* for January, 1878. Figs. 2960 and 2961 are two views of an oil-testing machine patented by Prof. Thurston, who describes its construction and operation as follows:

"The machine is fitted for a wide range of pressures, as is seen on the index-plate $M N$, on the pendulum $H H$, where the large figures represent the total pressures on the journal, and those opposite the corresponding pressures per square inch. The speed of the machine, when the belt is upon the largest pulley of the cone C, should be that which will give the least speed of rubbing at the surface of the testing journal, which is to be usually adopted. The figures on the arc $P P'$, traversed by the pointer O, attached to the pendulum, are such that the quotient of the reading on the arc $P P'$, by the total pressure read from the front of the pendulum at $M N$, gives the 'coefficient of friction,' i. e., the proportion of that pressure which measures the resistance due to friction. A printed table is furnished with each machine, giving these coefficients for a wide range of pressures and arc-readings.

"*To determine the lubricating quality*, we remove the pendulum $H H$ from testing journal $G G'$, adjust the machine to run at the desired pressure by turning the screw-head K, projecting from the lower end of the pendulum, until the index M, above, shows the right pressure, and adjust it to run at the required speed by placing the belt on the right pulley, C. We then throw out the bearings by means of the two little cams on the head of the pendulum H; we next carefully slide the pendulum upon the testing journal $G G'$, and see that no scratching of journal or brasses takes place. Then we oil the journal through the oil-cups or the oil-holes, set the machine in motion, running it a moment until the oil is well distributed over the journal. Next stop the machine; loosen the nut or the cams which confine the spring, and, when it is fairly in contact and bearing on the lower brass with full pressure, turn the brass nut or the cams fairly out in contact, so that the spring may not be jammed by their shaking back while working. Now, start the machine again and run until the behavior of the oil is determined, keeping up a free feed throughout the experiment. At intervals of one or more minutes, as may prove most satisfactory, observe and record the temperature given by the thermometer $Q Q'$, and the reading indicated on the arc P' of the machine by the pointer O. When both readings have ceased to vary, the experiment may be terminated. Remove the pendulum, first relieving the pressure of the spring, and clean the journal and brasses with exceedingly great care from every sign of grease; and be especially careful not to leave a particle of lint on either surface, or any grease in the oil-cup or oil-passages. A comparison of the results thus obtained with several oils will show their relative values as reducers of friction. In each case we record, in tables like the blanks which are sent with the machine: 1. The pressure and speed of rubbing at each trial; 2. The observed temperature; 3. The readings on the arc of the machine; 4. The calculated coefficients of friction. We enter at the end of the trial the average and the minimum coefficients, and the total distance *rubbed over* by the bearing surfaces.

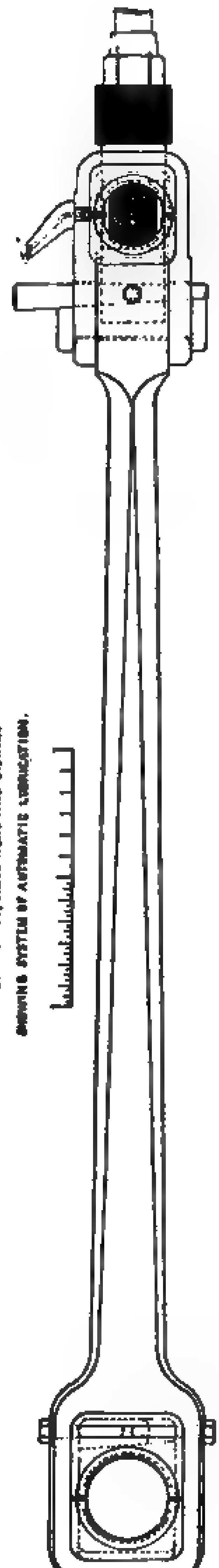
"*To determine the liability of the oil to gum*, we allow the machine to stand with the journal wet with oil, but with none feeding through the bearing, for 12 or 24 hours or more, as may be found necessary. Then start up and run a few moments until the reading on the arc $P P'$, having fallen to a minimum, begins to rise again; then stop *at once*. Compare the minimum coefficients thus obtained from the several oils to be examined; that which gives the smallest figure will be least liable to gum during the period of time given to the test.

"*To determine durability*, we proceed as in determining the friction, except that the lubricant should not be continuously supplied, but should be fed to the bearing, a small and definite portion at a time—say a drop for each 2 inches length of journal. Extreme care should be taken that each portion actually reaches the journal, and is not lost either in the oil-hole or by being wiped off the journal, and that the portions applied are *exactly* equal. When the friction, as shown by the pointer *O*, has passed a minimum and begins to rise, the machine should be carefully watched, and should be stopped either at the instant that the friction has reached double the minimum, or when the thermometer indicates 212° F.; or else another portion of the lubricant should be then applied to the journal. This operation should be repeated until the duration of each trial becomes nearly the same; an average may then be taken either of the time, of the number of revolutions, or of the distance rubbed over by the bearing, which average will measure the durability of that lubricant. Next, we carefully clean the testing journal, and proceed as before with the next oil to be tested. In making comparisons we always test the standard as well as the competing oils on the same journal and under precisely the same conditions. We are compelled to be exceedingly careful of the testing journal. A scratch will alter the conditions, sometimes, to a measurable degree. For nice work, the size of drops is very carefully preserved constant. It is sometimes weighed on a chemist's balance. For rough work, a dropper, such as is used for medicine, with careful handling, will do very well. I have had very good work done by dropping the oil from a No. 8 wire, filed smoothly to rather a blunt point. Dipping it in the oil, the first drops, when held vertical, are variable, but after a half minute or so they become uniform. We use the drop that falls after the expiration of three-quarters of a minute. This wire yields drops of sperm, at that instant, weighing 8 milligrammes. We are always careful to see that the testing journal has a little end-play in its bearings, and keep it moving during the test, to keep the oil distributed."

A record of experiments made with this machine on the ordinary commercial oils was published in the *Polytechnic Review* for April, 1877. The surface speed of the journal was about 750 feet per minute; the pressures varied from 8 to 48 lbs. per square inch; the coefficient of friction varied with the different oils and pressures from 0.07 to 0.17, and the rise of temperature under the same circumstances from 105° to 375° F. Prof. Thurston's experiments are fully detailed in his work on "Friction and Lubrication," New York, 1879.

Various contrivances have been proposed for indicating an undue rise in the temperature of a bearing. Prof. Mayer has suggested that the shaft be covered with a composition that shall change to a bright-red color when a given temperature is reached. R. H. B.

LUBRICATORS. The necessity of keeping the working parts of an engine well lubricated must be apparent; and automatic lubricators are frequently employed, to furnish a constant supply. Oil-cups containing wicks which act after the manner of siphons are frequently used on the guides and shaft-journals, and the same attachments are sometimes fitted to crank and cross-head pins. Oil-cups are also attached to these pins by telescopic pipes, so that the oil-cups are stationary, and are at the same time in constant communication with the moving



CONNECTING ROD, CROSS HEAD AND CRANK.
SHOWING SYSTEM OF AUTOMATIC LUBRICATION.

pins. A very neat and effective system for the continuous lubrication of these pins automatically is used on the Porter-Allen engine, and illustrated in Figs. 2962 and 2963. It will be observed that the inner end of the connecting-rod carries a projecting tube, which communicates with the cross-head pin, and which strikes the wick of a stationary oil-cup at each revolution, thus conveying oil to the pin. The crank also carries a projecting tube, communicating as shown with the surface of the crank-pin, and striking the wick of an oil-cup at each revolution of the engine. Although but a small supply of oil is taken up by these tubes at each revolution, the action is continuous, and the pins receive sufficient oil to keep them always cool. It may be proper to call attention to the peculiar form of connecting-rod shown in these figures. It will be seen that it is flat, so that it can be made comparatively narrow, and placed closer to the crank than is possible with the ordinary form. The cross-head pin, it will be seen, is flattened on two sides. The advantage of this mode of construction, which is representative of the best practice, is obvious.

2964.

The internal working surfaces of an engine, that is, the valves and seats, piston and cylinder, also require to be lubricated; and there are numerous continuous cylinder lubricators in the market, some of them quite complicated in structure. It is doubtful, however, if any of them are more effective than the simple contrivance used on the Porter-Allen engine, and illustrated in Fig. 2964. The cup here shown has only to be filled with oil, and the valve regulated to give the proper supply, when steam will enter from the chest, condense, and displace the oil, which thus finds its way gradually into the steam-chest and cylinder. Lubricators of this general form are largely used in Europe, and a general account of their various modifications, with descriptions of other forms, will be found in the "Transactions of the Society of Engineers" for 1870. R. H. B.

MACHINE CONSTRUCTION, PRINCIPLES OF. A machine is a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work, accompanied by certain determinate motions. (For definitions of the term given by nearly all the best authorities on the science of mechanism, see note 7, Reuleaux's "Kinematics of Machinery," New York and London, 1876, from which work the following discussion is abridged.) While the science of mechanics examines motion caused in the most general cases by the action of mechanical forces, machine mechanics occupies itself with certain special cases only, with motions produced by a limited circle of means. The study of practical mechanics is divided by Reuleaux into the following parts: 1. The study of machinery in general, looked at in connection with the work to be performed. This teaches what machines exist and how they are constituted. 2. The theory of machines, which concerns itself with the nature of the various arrangements by means of which natural forces can best be applied to machinery. 3. The study of machine design, the province of which is to teach how to give the bodies constituting the machine the capacity to resist alterations of form. 4. The study of pure mechanism, or of kinematics, which relates to the arrangements of the machine by which the mutual motions of its parts, considered as changes of position, are determined.

It will readily be apprehended that the larger number of articles in the present work deal with machinery with regard to what it accomplishes and how it is actuated, and therefore supply means for study under the first and second subdivisions. The third branch is treated briefly under STRENGTH OF MATERIALS, and also in the present article. The fourth branch, or the basis on which all machines rest, is now to be considered.

Kinematic Elements.—In order that any moving body (which, for brevity's sake, may be termed A) of given form may remain continually in contact with a stationary one (B), we must give the latter a special form. This can be found if the body A be caused to take up consecutively a series of positions which it is intended to occupy relatively to B, and the figure which envelops all the positions of outline of the body A be determined. The geometrical form thus found for B is called the envelope of A. The relation is therefore reciprocal. We see that at least one other body is necessary for the envelopment of a moving form. If it be found necessary to use several—perhaps because the one first found, while actually forming an envelope, does not exclude all motions but the one required—then these can be united with the first into one body. Thus, for instance, we can suppose the upper and lower half brasses of a plumber-block joined together.

We find that in all cases at least two bodies correspond in being reciprocally envelopes each of the other. A machine consists solely of bodies which correspond pairwise reciprocally. These form the kinematic or mechanismal elements of the machine. The shaft and bearing, screw and nut, are examples.

The Kinematic Chain.—If a kinematic pair of elements be given, a definite motion can be obtained by means of them if one of the two be held fast or fixed in position. The other element is then free to be moved, but only in one particular way allowed by the constitution of the pair. Thus, on a fixed screw a nut can only be traversed up and down. A large number of motions can be obtained in this way simply by pairs of elements, and we may multiply indefinitely the motions obtain-

able by single pairs by combination. With different methods of combination different results are obtained, but in every case there results only one pair. Accordingly, the reciprocal combination of the elements of two pairs gives us again a pair of elements, which may differ from either of the single pairs of which it is composed. Similarly three or four pairs may be combined and called a chain, or more fully a kinematic chain.

The body which is formed by the junction of the elements of two different pairs is then a link in the kinematic chain. Every link of the chain consists of two elements, so that the chain has as many links as it contains pairs. In every chain, every two adjacent lengths have a definite relative motion, that namely which belongs to the pair of elements connecting them. But two links which are connected by a third link do not possess reciprocal motions except under certain conditions. Such motions can occur only if the chain be so arranged that every alteration in position of a link relative to the one next to it be accompanied by an alteration in the position of every other link relatively to the first. Such a kinematic chain is called a constrained closed (or simply a closed) chain.

In itself a closed chain does not postulate any definite absolute motion. In order to obtain this, a similar method must be adopted to the one employed above with pairs of elements: namely, to hold fast or fix in position one link of the chain relatively to the portion of surrounding space assumed to be stationary. The relative motions of the links then become absolute. A closed kinematic chain of which one link is thus made stationary is called a mechanism. Let a chain be composed of four pieces pivoted together at the angles. It will be evident that either one of the pieces may be held stationary and the others moved in relation to it. Hence, in general, a constrained closed kinematic chain can be formed into a mechanism in as many ways as it has links. Moreover, an element of a new pair can be combined with a closed chain, and the latter be thus further extended. In order to obtain at the same time the requisite closure, this extended chain must be brought back again in connection with the link at which it started. In this way is produced a compound kinematic chain, in contradistinction to a simple one.

Closed mechanisms can also again combine, and so unite into higher forms. We may, however, class these compound mechanisms with those built up from simple chains.

We have now before us a general view of the method of construction of mechanisms. The mechanism is a closed kinematic chain. The kinematic chain is compound or simple, and consists of kinematic pairs of elements. These carry the envelopes required for the motion which the bodies in contact must have, and by these all motions other than those desired in the mechanism are prevented. A kinematic mechanism is moved if a mechanical force or effort be applied to one of the movable links in such a way as to alter the position. The effort thus applied performs mechanical work which is accompanied by determinate motions; the whole is therefore a machine.

Load.—By the load on any member of a machine is meant the aggregate of all the external forces in action upon it. These may be distinguished as (1) the *useful load*, or the forces arising out of the useful power transmitted, and (2) the *prejudicial resistances* due to friction, to work uselessly expended, to weight of members of the machine, to inertia due to changes in velocity of motion, and to special stresses caused in the apparatus by changes in its parts through variations of temperature.

Each member of a machine must be capable of sustaining the maximum straining action for that part of the machine. If this straining action be different at different times, the member must be capable of sustaining the maximum straining action of each kind. There are various straining actions affecting a machine which are either individually so small as to be neglected in computations, or which cannot be accurately determined. In order to allow for these, and supply a margin of resistances sufficient for all contingencies, it is customary to increase the estimated amount of stress due to the forces, which are reckoned by multiplying the aggregate by a *factor of safety*, which is determined by practical experience in similar cases.

Kinds of Load.—There are two kinds of load: first, steady load, which produces a permanent and unvarying amount of straining action, and is invariable during the life of the machine—such, for example, as its weight; and second, variable or live load, which is alternately imposed and removed, and which produces a constantly varying amount of straining action. Every load which acts on a structure produces a change of form, which is termed the strain due to the load. The strain may be either a vanishing or elastic deformation, that is, one which disappears when the load is removed; or a permanent deformation or set, which remains after the load is removed. In general, machine parts must be so designed that, under the maximum straining action, there is no sensible permanent deformation.

The strength of materials entering into machine construction is measured by the resistance which they oppose to alteration of form, and ultimately to rupture, when subjected to force, pressure, load, stress, or strain.

Stress is applied in five recognized modes: 1. Tensile stress, tending to draw or pull the body asunder, the immediate effect of which is elongation; 2. Compressive stress, tending to crush it, the immediate effect of which is compression; 3. Shearing stress, tending to cut it through, the immediate effect of which is lateral compression, elongation, and deflection; 4. Transverse or lateral stress, tending to bend it and break it across, the force being applied laterally and acting with leverage; its immediate effect is lateral deflection; 5. Torsional stress, tending to twist it asunder, the force acting with leverage; its immediate is angular deflection.

Safe Working Intensity of Stress.—If the stress corresponding to the elastic limit be divided by the factor of safety, we get the permissible working intensity of stress, due to those straining actions which are taken into account in estimating the strength of the structure. Although this is usually termed the greatest safe intensity of stress (or for brevity greatest safe stress), it is, in most cases, less than the real intensity of the stresses induced by the actual straining actions. The resistance corresponding to the greatest safe intensity of stress may be termed the working strength of the piece.

Ultimate Strength.—If the straining action on a bar is gradually increased till the bar breaks, the load which produces fracture is called the ultimate or breaking strength of the bar. That ultimate strength is for different materials more or less roughly proportional to the elastic strength. We may insure the safety of a structure by taking care to multiply the actual straining action by a factor sufficiently large to allow, not only for unforeseen contingencies and the neglected causes of straining, but also for the difference between the elastic and ultimate strength. The actual straining action multiplied by this factor, which is still termed a factor of safety, is then equated to the ultimate strength of the structure. The value of the factor of safety must, as in other cases, be determined by practical experience.

On the Peculiar Action of Live Loads.—The researches of Wöhler, since repeated by Spangenberg (see "The Fatigue of Metals under Repeated Strains," New York, 1876), show that the safety of a structure, subjected to a varying amount of straining action, depends on the *range of variation* of stress to which the structure is subjected, and on the number of repetitions of the change of load. It has been hitherto assumed that it depends only on the maximum intensity of the stress; but this must now be considered to be erroneous. Every machine subjected to a constant variation of load must be designed to resist a practically infinite number of changes of load. In order that it may do so, the greatest intensity of stress must be less than for a steady load, and less in some proportion which depends on the amount of variation the stress undergoes in its successive changes.

A steady load has already been defined as one which remains invariable during the life of the structure. Let the intensity of stress required to fracture a given material under a steady load be denoted by K, so that K is what is commonly termed the breaking strength of the material. In designing a machine part to sustain a steady load, the greatest safe stress is commonly taken at about $\frac{1}{2}$ to $\frac{1}{3}$ K. With a live or variable load, it has been usual to take a higher factor of safety, and to restrict the working stress to $\frac{1}{4}$ or $\frac{1}{6}$ K, or to some other limit, ascertained by practical experience in special cases. Wöhler's researches show that this is not a scientific way of dealing with the question. Suppose that under the action of the live load the stress varies from $\sigma_{max.}$ to $\sigma_{min.}$, and that the range of variation $= \Delta = \sigma_{max.} - \sigma_{min.}$ In using this expression, if tensile stresses are reckoned positive, compressive stresses must be reckoned negative, so that, if the two stresses are of different sign, the range of stress is equal to their sum $[\sigma_{max.} - (-\sigma_{min.}) = \sigma_{max.} + \sigma_{min.}]$. Let the number of changes of load be indefinitely great. Then Wöhler's researches show that fracture will occur for some value of $\sigma_{max.}$ less than K, and so much smaller, the greater the range of stress Δ. Hence, in designing a structure for such a varying load, the ultimate strength is to be taken at some value $k < K$, which is to be determined with reference to Δ.

For example, Wöhler found that a bar was equally safe to resist varying bending and tensile straining actions, repeated for an indefinite time, when the maximum and minimum stresses had the following values:

For Wrought Iron.	Pounds per sq. in.
In tension only	+ 18,713 to + 31
In tension and compression alternately	+ 8,317 to − 8,317

For Cast Steel.	Pounds per sq. in.
In tension only	+ 34,307 to + 113,436
In tension and compression alternately	+ 12,475 to − 12,475

These results are sufficient to show that, as the range of stress increases, the maximum stress should be reduced. Unfortunately, Wöhler's experiments, although extensive, do not furnish decisive rules for practical guidance. They afford an explanation of the apparently high factors of safety which in certain cases experience has shown to be necessary, but they are not complete enough to indicate precisely the factor of safety to be chosen in different cases. Nor indeed could rules be obtained, without the most careful comparison of the results of researches, of the kind begun by Wöhler, with the actual stresses found to be safe in practice, in a great variety of cases.

Let, as before, K be the breaking strength per square inch for a gradually applied load, for any given material; k, the breaking strength for a variable load, repeated an indefinitely great number of times, and producing alternately the stresses $\sigma_{max.}$ and $\sigma_{min.}$ Let $\Delta = \sigma_{max.} - \sigma_{min.}$ Then Wöhler's experiments appear to suggest a rule of the following kind, as giving the relation between k and K: $k = \frac{\Delta}{2} \pm \sqrt{(K^2 - n\,\Delta\,K)}$, where the + sign is to be taken if Δ is +, and the − sign if Δ is −. This, however, must be regarded at present as an empirical rule only, based on experimental results. The value of n appears to be about 1.5 for iron, and not very different for steel.

The cases most useful to consider are: 1, when the load changes from a maximum intensity to zero, the stress remaining of the same sign; 2, when the load changes from one direction to the opposite direction, so as to produce equal stresses of opposite sign. In the former case $\Delta = \sigma_{max.} = k$; in the latter case $\Delta = 2\,\sigma_{max.} = 2\,k$. By solving the equation above we get: For case 1, $k = K(\sqrt{13} - 3) = .6056\,K$; for case 2, $k = \frac{1}{3}\,K$.

Thus, for instance, wrought iron, with an ultimate strength of 54,000 lbs. per square inch, would safely bear, under a steady load, from 27,000 to 18,000 lbs. per square inch. With a load such as that in case 1, its ultimate strength would be $k = 32{,}700$ lbs. per square inch, and the greatest safe load, with the same factors of safety, would be 16,350 to 10,900 lbs., which agrees fairly well with experience of structures subjected to tension only. For such a load as that in case 2, the ultimate strength would be $k = 18{,}000$ lbs., and the greatest safe stress 9,000 to 6,000 lbs. per square inch, which is not very different from the stress allowed in axles and similar parts subjected to constant

alteration of the direction of the straining action. (See also "Iron and Steel Constructions," Weyrauch, New York, 1876.)

Straining Action due to Power transmitted.—When HP horses' power are transmitted through a link or connecting-rod moving with velocity v, in feet per second, the straining force, parallel to the axis of the rod, due to the work transmitted, is $P = \frac{550\ HP}{v}$ lbs. There will be in this case other straining actions, due to the reactions of the supports of the link, if the link is not moving parallel to its axis.

When HP horses' power are transmitted through a rotating piece, making N revolutions per second, the moment of the straining force about the centre of the piece is given by the equation $M = \frac{550\ HP}{2\pi N} = 1050.4\ \frac{HP}{N}$ inch-pounds.

Among other straining effects are those produced by the acceleration or retardation of a heavy body and due to its inertia, and those due to change of direction of motion. The quantity of work expended in deforming a bar (provided the stress does not exceed the elastic limit) is equal to the product of the deformation and the mean load producing it. Thus, if a bar be elongated or deflected a feet by a force gradually increased from nothing to P, the work done in deformation is $a \times \frac{P}{2}$ in foot-pounds. A heavy body of weight W moving with a velocity V has $\frac{W}{g} \cdot \frac{V^2}{2}$ foot-pounds of work stored in it. Hence the relation between the impulsive load and the resistance of the bar, when the direction of the impulse coincides with the direction of the deformation, is $\frac{W}{2g} V^2 = \frac{1}{2} Pa$. If a bar is twisted, the work done is equal to half the twisting moment multiplied by the angle of torsion. The work done in deforming a bar up to the elastic limit is termed the resilience of the bar.

Works for Reference.—"Elements of Machine Design," Unwin, New York, 1876, and "A Manual of Rules, Tables, and Data for Mechanical Engineers," Clark, London and New York, 1877, from both of which extracts are embodied in the foregoing. See also list of works of reference under MECHANICS and STRENGTH OF MATERIALS.

MAGAZINE GUN. See FIRE-ARMS, CONSTRUCTION OF.

MAGAZINE STOVE. See STOVES AND HEATING FURNACES.

MAGNETS. A magnet is a body, consisting usually of iron or steel, which has the property of attracting iron and other magnetic bodies, and which also possesses a certain two-endedness (polarity), in consequence of which two similar ends (poles) of two magnets if brought within the necessary distance repel, and two dissimilar ends (poles) attract each other. Magnets are either natural or artificial. A *magnetic body* is a substance which has the property of attracting and being attracted by both ends of a magnet, and which is not repelled by either end. The only bodies which possess decided magnetic properties are iron (including steel and some of its compounds) and, in a much lower degree, chromium, cobalt, nickel, and manganese. Magnetic bodies do not attract or repel each other.

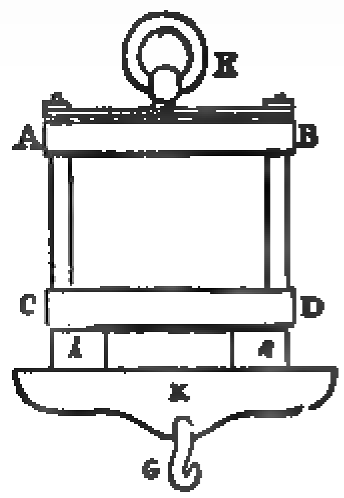
NATURAL MAGNETS.—Hitherto but one substance possessing the properties of a magnet has been found in nature. This is the compound commonly called loadstone, consisting of iron and oxygen, united in the proportion of three atoms of iron to four of oxygen, and represented chemically by the symbol Fe_3O_4. This oxide has been variously termed magnetic oxide and black oxide of iron. It is found largely in nature, forming a very pure ore, from which the best iron is extracted. It exists abundantly in Sweden and Norway, where it forms entire mountains, and also in many parts of the United States. Its color varies from a reddish brown or black to a deep gray. It is about 4½ times as heavy as water, and crystallizes in cubes, octohedra, or dodecahedra. This oxide acquires its power as a magnet from the inductive action of the earth exercised upon it when lying in its natural bed as rock or vein. A very small portion of it, however, possesses any marked power of attraction as a magnet, its powers in this respect being in general very feeble and almost inappreciable. Loadstones possessing any considerable degree of attractive power are very rare. Small loadstones usually are more powerful in proportion to their size than larger ones. Occasionally, however, small native or natural magnets have been found possessing extraordinary attractive power. Sir Isaac Newton is said to have owned a small natural magnet, weighing about three grains, set and mounted in a ring worn by him, which would lift about 250 times its own weight. A native magnet presented by the Emperor of China to King John V. of Portugal, which weighed 38 lbs., was capable of supporting about five times its own weight, or about 200 lbs. Natural magnets of any size are rarely homogeneous, or of uniform structure or power throughout. It therefore often happens that a portion of a loadstone cut from a larger one will support a greater weight than the large one itself. Loadstone possesses the remarkable property of communicating its own powers *permanently* to hardened and tempered steel by the mere act of rubbing, and *temporarily* to soft iron by contact or even mere proximity.

If a piece of loadstone be rolled in fine iron or steel filings, and then withdrawn, a considerable portion of the filings will be found to adhere to the stone, most of them being collected at two opposite points. These points at which the magnetic force seems to concentrate are called the *poles* of the magnet; the line joining the middle of the poles is called the *axis*, and the middle line perpendicular to the axis is termed the *neutral line*. At the true neutral line no filings adhere, but the filings increase in quantity as the poles are approached. Sometimes a loadstone has several poles.

Each particle of iron filing attracted becomes itself a magnet temporarily when under the influence of the magnet. This is more clearly shown by allowing the magnet to attract a small piece of iron. A second piece of iron will then be attracted by the first, a third by the second, and so on, until the weight of all the pieces exceeds the portative force of the loadstone. The usual method of mounting natural magnets is shown in Figs. 2965 and 2966. The effective power and usefulness of the loadstone are greatly increased by the armatures *a* and *b*, Fig. 2965, as will be explained in considering artificial magnets. The loadstone should have its polar faces ground flat, and be mounted in the armatures, which should be of the shape shown, and be of pure soft iron. Each armature consists of a vertical portion of say a quarter of an inch, and a projecting solid foot of about an inch in thick-

2965.

2966.



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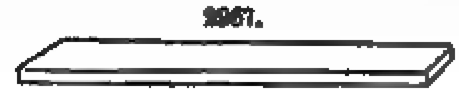

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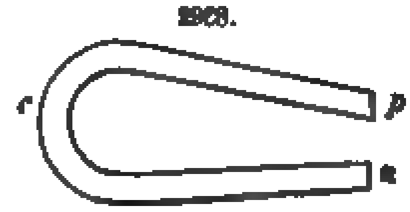

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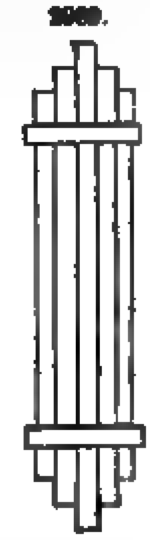


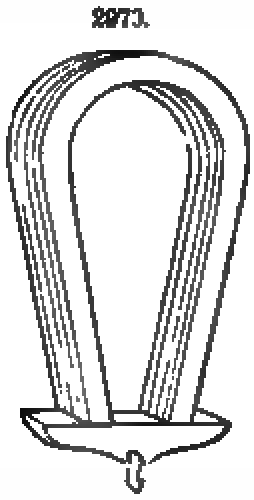
ness. The tops of the armatures are bound together by a brass cap *A B*, with a ring *R* for purposes of suspension, and the lower portions by a brass band *C D* passing just above the feet. The magnet may be strengthened up to a certain point, or its power preserved, by the addition of a soft iron bar *K*, termed a *keeper* or lifter. This is usually supplied with a hook *G* for lifting weights. The laws of magnetism will be explained in another section of this article.

Artificial Magnets.—When a piece of steel which has been properly hardened and tempered is rubbed with a piece of loadstone or by any other magnet, or when a current of electricity is passed around it by means of a coil of insulated wire (see Electro-Magnet), it becomes a more or less powerful artificial magnet. The most usual form of artificial magnet is that of a bar or horse-shoe, as shown in Figs. 2967 and 2968. When single they are termed single magnets. When consisting of several joined together so that their similar poles are adjacent, they are termed *compound magnets*, Figs. 2969 and 2970. The latter are sometimes designated as *magnetic batteries*. A magnetic battery is therefore simply a bundle of magnets with their similar poles placed together.

Methods of Making Artificial Magnets.—There are three principal methods, known as the method of single touch, separate touch, and double touch.

By single touch.—This is most applicable to small magnets. To magnetize by the loadstone, procure a small bar of steel about 8 inches long, one fourth of an inch wide, and one-eighth of an inch thick, or a piece of common steel wire of about the same length, and from one-eighth to one-fourth of an inch in diameter. Let the steel be well hardened and tempered by plunging it at a cherry-red

2970.



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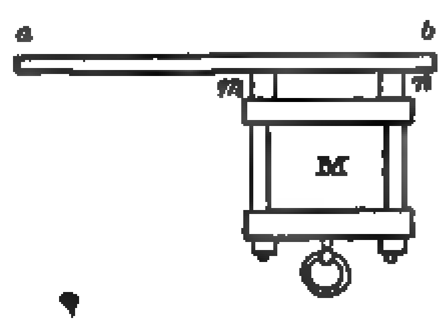

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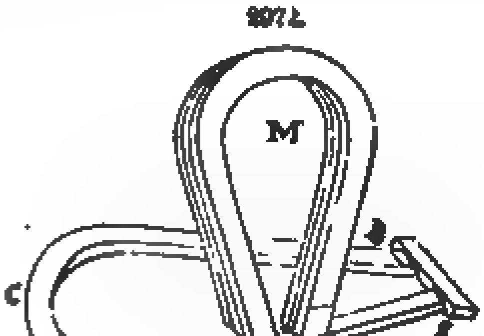
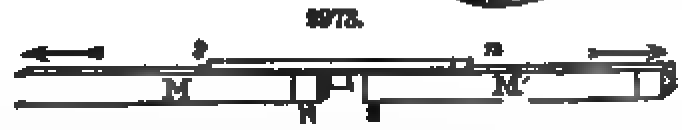


2973.



heat into cold water; when cold and polished, apply each extremity in succession to the opposite poles of an armed magnet, Fig. 2965, first touching with gentle friction one extremity of the bar, or one of the poles, and the opposite extremity on the other pole; or, which is better, draw the bar *a b*, Fig. 2971, a few times in the direction of its length, across the two poles *m n* of the magnet *M*, as represented in the figure, and in such a way as not to pass either extremity *a b* beyond or off the opposite poles *m n*; finally, bring the bar *a b* so as to rest with its extremities equally distant from each pole *m n*; that is to say, bring the poles *m n* at the centre of the bar, or as nearly as may be. In this position remove the bar from the poles. The bar will now be found attractive of particles of iron, common steel needles, and other ferruginous matter; when suspended it will arrange itself in the

direction of the magnetic meridian, and will, in fact, have all the properties of the loadstone, including the important property of imparting or exciting a magnetic condition in tempered steel.

To magnetize a horse-shoe magnet by means of a compound artificial magnet, place the bar, as shown in Fig. 2972, on a flat board, with its extremities against a straight piece of soft iron, *p s*, of the same thickness and width as the bar. Having secured the whole in this position, place a compound magnet *M*, or an armed native magnet, on the extremity *s* of the curved bar, taking care that the opposite or marked and unmarked ends are in contact with each other. Continue as before to glide the magnet *M* several times round the whole series, and in the same direction *s c p*, finally stopping in the centre *c*. Repeat this process on each face of the bar, when a high degree of power will have become developed; so much so, that the iron or keeper *p s* cannot be directly pulled away without considerable force, and in some instances cannot be conveniently removed except by sliding it off. In order to preserve effectually the magnetism thus excited in bars of steel, it is requisite, when not in use, to keep their opposite poles united by means of pieces of soft iron.

The following is an excellent method of making a powerful magnetic battery: Procure say ten flat bars of good steel bent like a horse-shoe; let these be well hardened and fitted with their flat sides together so as to form a compound magnet. Each of the members of this bundle may be magnetized separately to a small degree by supporting one of the legs on the lower end of a long rod of iron held nearly perpendicular in this latitude, and the other leg on the upper end of the same rod; or by rubbing one leg with the north pole of a magnetized bar, and the other with the south pole. The several shoes or bars being in this way feebly magnetized, eight of them are joined together with their similar poles in contact, forming a compound magnet with which the remaining two bars are to be magnetized to a higher degree. For this purpose the latter are placed on a table on their flat sides, the north pole of the one in contact with the south pole of the other, so as to form a closed circuit; on any point of this circuit the compound horse-shoe is placed perpendicular to the plane of the table, with its north pole in the direction of the south pole of the bar or shoe on which it rests, and then caused to slide in either direction entirely around the circuit, care being taken to retain its perpendicularity. After having gone over the surface of the two shoes in this way several times, they are turned over without separating their ends, and the process is repeated on the side which was previously under. By this method the two bars will receive a magnetic power nearly equal to the sum of the powers of the eight magnets in the bundle. Next these two bars are placed in the bundle, and two others are taken out and subjected to the same process. These in turn are put into the bundle, and two others are taken out and rubbed in the same way, until each pair of bars has been gone over two or three times in succession. By this method, with the most feeble beginning, the magnetism of the several shoes may be developed to their full capacity, and a magnetic battery produced of great power.

By separate touch.—This method, first used by Dr. Knight in 1745, consists in placing the two opposite poles of two magnets *M M'*, Fig. 2973, of equal force, in the middle of the bar *s n* to be magnetized, and moving each of them simultaneously toward the opposite ends of the bar as indicated by the arrows. Each magnet is then placed in its original position, and the operation is repeated. After several frictions on both faces, the bar is magnetized. Duhamel's improvement on Knight's method consists in inclining the magnets, and still more in placing the bar to be magnetized on the opposite poles of two fixed magnets, the action of which strengthens that of the movable magnets. This method produces the most regular magnets, and is best suited for compass-needles.

By double touch.—In this method, which was invented by Mitchell, the two magnets are placed with their poles opposite each other in the middle of the bar to be magnetized. But instead of moving them in opposite directions toward the two ends, as in the method of separate touch, they are kept at a fixed distance by means of a piece of wood placed between them, and are simultaneously moved first toward one end, then from this to the other end, repeating this operation several times, and finishing in the middle, taking care that each half of the bar receives the same number of frictions. This method has been improved by supporting the bar to be magnetized, as in the method of separate touch, on the opposite poles of two powerful magnets, and by inclining the bars at an angle of 15° to 20°.

Magnetization by Action of the Earth.—If a bar of soft iron to be magnetized be suspended in the magnetic meridian—that is, so that it shall point in the direction nearly north and south of the compass-needle—and also in the *line of dip* (about 70° with the horizon), it becomes possessed of a weak magnetic polarity, and steel filings will be immediately attracted. If, however, the bar be of hardened steel, its magnetism will require a few minutes to arrive at its maximum intensity, because of its coercive forces causing it for a short time to resist magnetization. If the suspended bar be struck smartly several times in rapid succession, the process of magnetization is quickened and the magnetism rendered more permanent. If the bar, being of soft iron, be twisted or bent while in its state of temporary magnetism, it tends to retain a portion of its magnetism, thus becoming a weak permanent magnet. The magnetization here described is brought about by the inductive action of the earth, which is in fact a huge magnet. To the same cause is due the magnetism frequently observed in steel and iron instruments, such as fire-irons, lamp-posts, railings, lightning-conductors, etc., which remain for some time in a more or less inclined position. They become magnetized with their north pole downward, the same as if placed over the pole of a powerful magnet.

The Jamin Magnet.—The ordinary way of determining the power of a magnet consists in applying an armature and measuring the amount of weight which, attached thereto, the magnet will sustain. This plan, besides being crude, frequently involves error, since it may easily happen that one magnet, in reality better than another, will yield to a less weight, while a very slight modification of the polar faces often results in very great differences in the total which a magnet is capable of supporting. M. Jamin's device for overcoming these difficulties consists simply of a nail suspended by a string from the arm of a balance. The nail, presented at various points of a magnetized bar or at

corresponding points of several bars, is attracted, and the degree of attraction is noted by the balance, so that it is obviously easy thus to measure the magnetism of different localities, and to compare several magnetized plates with each other. If several magnetized bars are superposed, it has been found that the attraction (measured at the extremity of the assemblage by means of the nail) augments with the number of bars, and then becomes stationary. To illustrate, one bar or plate attracts the nail with a certain force, say 750 grains; two plates, superposed, exercise a force of 875 grains; three, 1,425 grains; four, 1,575; and five, either the same as four, or perhaps 15 grains more. The fifth plate, therefore, adds nothing, or nearly nothing, although it has been magnetized in the same manner as the others, and when tested singly is as powerful as any one of them. This, however, is not all: if the plates be separated and reëxamined, it is found that they are less powerful than before, and that their union has resulted in loss. They have, in other words, acted upon each other unfavorably. M. Jamin has discovered that these facts are not exceptional or fortuitous, but absolutely constant and regular; and he has also found a means of preventing this tendency of the superposed plates toward mutual deterioration. This means is simply the attaching to the ends of the bundle of plates of pieces of soft iron which partake of the magnetism of the extremities. If, under these new conditions, the experiment above described be repeated, the fifth plate is found to add as much as its predecessors, and the number of plates may be largely augmented before the effects noticeable in the former case manifest themselves. Finally, with a certain number of plates, 20 for example, the soft-iron pieces become saturated with magnetism, and further additions are of no value or are mutually injurious. If, instead of employing bars, thin ribbons of steel be used, superposed as above explained, the magnet invented by M. Jamin, and represented in Fig. 2974, is obtained. The plates are curved, and the poles, brought near together, are separated by a piece of brass to which they are firmly screwed. Perhaps the most important advantage gained by this form is the facility with which the magnet may be taken apart and put together, or with which the number of plates, and consequently the degree of magnetism, may be varied.

2974.

One form of magnet devised by M. Jamin is represented in Fig. 2975. The poles are of soft iron, and are applied to the extremities of several steel leaves, which are made broad in proportion to their length. Singly

2975.

the plates support but very small weights; but when combined with the iron end-pieces, the latter absorb the magnetism, rendering the assemblage sufficiently powerful to carry twice or three times its own weight. A very remarkable peculiarity of this magnet, which is not clearly explained, is that neither pole, when tested separately, has any very marked attractive force; but when the armature is applied simultaneously to both poles, it is very strongly held, and yet the attraction does not seem to act over any appreciable distance. It appears, in fact, that the magnetic current must be completed before the maximum force is developed. M. Jamin has constructed large magnets, the portative force of which equals ten times the weight. (See *Scientific American*, xxix., 383).

Laws of Magnetism.—In order to explain the phenomena of magnetism, the existence of the hypothetical magnetic fluids has been assumed, each of which acts repulsively on itself, but attracts the other fluid. The fluid predominating at the north pole of the magnet is called the *north* fluid, and that at the south pole, the *south* fluid. The mutual action of the poles is expressed by the law that *poles of the same name repel and poles of contrary name attract one another*. Magnetic attractions and repulsions are inversely as the square of the distances. To a certain degree the magnetic force which can be imparted to a bar or needle increases with the power of the magnets used. But there is a limit to the magnetic force which can be imparted to a bar or needle, and when this is attained the bar is said to be saturated or magnetized to saturation. A bar may be magnetized beyond this point, but this is not permanent; the magnetism gradually diminishes until it has sunk to the point of saturation. When a steel bar is at the limit of saturation, it gradually loses its mag-

netism. To prevent this, *armatures* or *keepers* are used, these being pieces of soft iron placed in contact with the poles. Acted on inductively, they become powerful magnets, possessing opposite polarity to that of the inducing pole, and thus react in turn on the permanent magnetism of the bars, preserving and even increasing it. The *portative force* is represented by the weight which a magnet can support. Häcker has determined that the portative force of a saturated horse-shoe magnet, which has become constant by repeatedly detaching its keeper, may be represented by the formula $P = a \sqrt[3]{p\,2}$, in which P is the portative force of the magnet, p the weight of the magnet, and a a coefficient which varies with the nature of the steel and the mode of magnetizing. In Häcker's magnets the value of a was 10.33, while in Logemann's it was 23.

The coercive force of a magnet is that force, agency, or influence, by which in a particular body or substance the north and south fluids resist separation, and by which when separated they resist recombination. The harder steel is, the greater its coercive force; it receives magnetism with much greater difficulty, but retains it more effectually. Compass-needles are usually tempered to a blue, or about 482° F. Increase of temperature produces a diminution of magnetic force. Small changes of temperature, such as those occurring in the atmosphere, do not permanently alter the magnet. If, however, the magnet is strongly heated, it does not regain its original force on cooling to its original temperature; and when it has been heated to redness it is demagnetized. Incandescent iron is not attracted by a magnet, thus proving that there is a *magnetic limit.* This for cobalt is beyond white heat, for at the highest temperatures hitherto examined the metal is still magnetic. The magnetic limit of chromium is somewhat below red heat; that of nickel at about 662° F., and of manganese at from about 59° to 68° F.

Magnetic attraction cannot be cut off by any substance interposed as a screen. It is as impossible to do this as to cut off the force of gravitation by similar means; and indeed to gravitation magnetism has many other points of similarity. Alleged magnetic motors, wherein the influence of permanent magnets is governed by interposed material of any kind, no matter how placed, are delusions. Thousands of inventors have wasted time and money in the vain pursuit of this chimerical idea. Any so-called magnetic motor is as utterly impracticable as the perpetual motion, of which it is but a specious form.

Paramagnetism and Diamagnetism.—It was formerly supposed that magnetism could be developed only in iron, nickel, and cobalt; but we now know, from the researches of Faraday, that all bodies exhibit signs of an inductive influence, provided the magnetic power applied be sufficiently great. From the results of his experiments, Faraday was led to divide all bodies into two great classes. Those like iron, nickel, and cobalt, which, on being suspended between the poles of an electro-magnet, assume an axial direction, were denominated magnetic bodies, or paramagnetic; while those which arrange themselves at right angles to the magnetic meridian were denominated diamagnetic. The following series exhibits some of the last results obtained by Faraday on the magnetic and diamagnetic powers of bodies, in which the angle of torsion necessary to balance the force of a magnet expresses the power of the various substances, volume for volume, + representing the paramagnetic bodies, and − the diamagnetic: proto-ammoniate of copper, +134.23°; oxygen, +17.5°; air, +3.4°; nitrogen, +0.3°; carbonic acid gas, 0.0°; hydrogen, −0.1°; glass, −18.2°; pure zinc, −74.6°; alcohol, −78.7°; wax, −86.73°; nitric acid, −87.96°; −water, 96.6°; sulphuric acid, −104.47°; sulphur, −118°; bismuth, −1967.6°.

Tyndall and Knoblauch established the fact that if the molecules of any body are more condensed in one direction than in any other, the magnetism will act along this direction with greatest intensity. If the substance is paramagnetic, the line of greatest condensation will assume an axial position; if diamagnetic, the same line will come into a state of rest in the equator. This is shown by mixing carbonate of iron with gum into a stiff paste, a disk of which, being compressed between the fingers so as to give a greater density in one direction, and afterward suspended between the poles of a powerful electro-magnet, will settle with its line of greatest condensation in the axial direction. If a similar experiment be made with a compound of powdered bismuth and gum, the line of greatest condensation of this factitious substance will assume an equatorial position.

APPLICATIONS OF MAGNETISM.—*Testing Iron by Magnetism.*—It has been discovered by Mr. S. M. Saxby, R. N., that magnets are advantageously used for detecting the presence of blow-holes, honeycombs, or other flaws in iron or steel. When a small compass-needle is slowly passed in front of a bar of very good iron, placed in an east and west direction, the needle will not be disturbed from its proper position, which is of course at right angles to this, or north and south. But this is true only with homogeneous bars of best quality, or bars without any mechanical solutions of continuity. With internal flaws or interruptions of continuity, the bar is no longer regularly magnetic. It has long been known that a good compass-needle or a good permanent magnet must be homogeneous and without flaws in order to take and retain its maximum amount of magnetism. Any mechanical solution of continuity is accompanied with a polar solution of continuity, and the given bar or mass with flaws—whether permanently magnetized or temporarily so by the inductive action of the earth—is no longer a regular magnet, but several different magnets, with the different magnetisms separated from each other. The delicately poised needle can thus be made to tell the presence of such solutions of continuity. In making tests practically, the bar is placed in the equatorial magnetic plane, or east and west. On moving the magnetic needle in a line parallel with the axis of the bar, as long as the iron is sound the needle remains north and south; but on the occurrence of a flaw the needle deviates more and more, until entirely reversed when placed over the imperfect spot. (See *Scientific American*, xviii., 20.)

The Mariner's Compass, made for service at sea, and especially for indicating the direction in which the ship's head points, consists of a needle attached to the under side of a circular card or disk, upon the top of which the cardinal points and their subdivisions are marked. A *fleur de lis* is on

the north pole of the needle, and the letter S. on the opposite pole. E. and W. are placed, the one to be toward the east and the other toward the west when the card, swinging with the needle, comes to rest, dividing the circle into quadrants. A diameter is drawn, bisecting each of these, fixing the N. E., S. W., N. W., and S. E. points upon the circumference; and the arcs thus obtained are again bisected by new diameters, again doubling the number of points; and the process is repeated upon the smaller arcs, obtaining in this way 32 points or divisions of the circle, each representing an arc of 11° 15′. The points are designated as follows for one quadrant, and on the same plan for the rest: N, Nb (by) E, NNE, NEbN, NE, NEbE, ENE, EbN, E. Lesser divisions sailors indicate by half and quarter points, thus: E. N. E. ½ E., N. E. ¼ N., E. ¾ N., etc. The degrees are also usually numbered around the margin of the circular card. An agate (or better a garnet) cap is set in the middle of the needle to receive the sharp pivot standing in the middle of the compass-box, upon which the needle and card are balanced. This box is of copper or brass, of cylindrical or hemispherical shape, and covered with a glass plate to exclude currents of air and dust. It is supported in a ring by two pivots projecting from opposite sides of the box, and this ring is swung by two other pivots placed so that the line connecting them is at right angles to that connecting the other two. This contrivance, called "gimbals," is designed to keep the central pivot always vertical in the movements of the ship, the box being made heavy at the bottom, so that its centre of gravity is considerably below the points of suspension, in which it swings freely. The pivots of the outer ring are fixed to a frame or to the inside of a square wooden box, in which the instrument is placed. Instead of using gimbals, a cap with a pivot standing in the top of it is sometimes placed upon the stationary pivot, and the needle is balanced upon the top of the upper one. On board ship the compass is set in a receptacle called the binnacle, and the direction in which the vessel heads is indicated by a distinct vertical mark on the inside of the inner box, close to which the points upon the card pass as this swings round.

Ritchie's liquid compass is made upon the principle of inclosing the magnetic needle in an air-tight metallic case, which, by its buoyancy in the liquid with which the bowl is filled, reduces the pressure on the pivot to a few grains. By this means friction is almost entirely prevented, and no perceptible wear takes place on the pivot or agate cap for many years. The liquid prevents the needle and card from oscillating or from being affected by the rolling of the vessel, but offers no resistance to the action of the polar force.

MALT-KILN. See KILN.

MANDREL. See LATHE-CHUCKS.

MANOMETER. See BOILERS, STEAM.

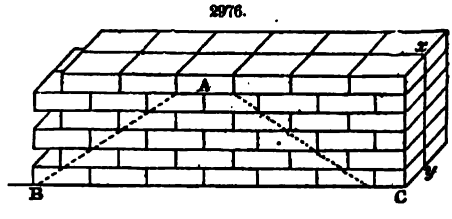
MARINE ENGINE. See ENGINES, STEAM, MARINE.

MASONRY. Under this heading will be considered: I. BRICKWORK; II. STONEWORK, or masonry proper. For building construction in wood, see CARPENTRY. See also BRICK-MAKING MACHINERY, CONCRETES AND CEMENTS, etc. The following is chiefly abridged from "Notes on Building Construction, arranged to meet the requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington" (London, 1876).

The following points should be attended to in walls of every description: The whole of the walling of a building should be carried up simultaneously; no part should be allowed to rise more than about 3 ft. above the rest, otherwise the portion first built will settle down and come to its bearing before the other is attached to it, and then the settlement which takes place in the newer portion will cause a rupture, and cracks will appear in the masonry. If it should be necessary to carry up one part of a wall before the other, the end of the portion first built should be "racked back"—that is, left in steps, each course projecting farther than the one above it. Work should not be hurried unless done in cement, but given time to take its bearings gradually. New work built in mortar should never be bonded to old, until the former has quite settled down. Then bonds may be inserted if required. As a rule, it is better that the new work should butt against the old, either with a straight joint visible on the face, or let into a slip-joint, so that the straight joint may not show; but if it be necessary to bond them together, the new work should be built in a quick-setting cement, and each part of it allowed to harden before being weighted. Even after walls are completed, they are likely to crack if unequally loaded. The walls of a building should either be perfectly vertical or at the required "batter" or inclination, and each course should be laid level in every direction, except in inclined or "battering" walls, when the courses should be at right angles to the line of inclination of the wall.

Bond is an arrangement of bricks or stones placed in juxtaposition, so as to prevent the vertical joint between any two bricks or stones falling into a continuous straight line with that between any other two. This is called "breaking joint," and when it is not properly carried out—that is, when two or more joints do fall into the same line, as at $x\,y$, Fig. 2976—they form what is called a *straight joint*. Straight joints split up and weaken the part of the wall in which they occur, and should therefore be avoided. A good bond breaks the vertical joints both in the length and thickness of the wall, giving the bricks or stones a good lap over one another in both directions, so as to afford as much hold as possible between the different parts of the wall. A further effect of the bond is to distribute the pressure which comes upon each brick over a large number of bricks below it. Thus, in Fig. 2976, there is a proper bond among the bricks forming the face of the wall, and the pressure upon the brick A is communicated to every brick within the triangle $A\,B\,C$. A defective

2976.



bond, either in brickwork or masonry, may look very well upon the face, as in this figure, where the bricks regularly break joint vertically, but in which there is no bond whatever across the thickness of the wall, which it will be seen is really composed of two distinct slices of brickwork, each 4¼ in. thick, and having no connection with one another except that afforded by the mortar. To avoid this defect, the bricks or stones forming a wall are not all laid in the same direction, as here, but some are laid parallel to the length of the wall, and others at right angles to them, so that the length of one of the latter overlaps the width of two below it.

Headers are bricks or stones whose lengths lie across the thickness of the wall, the ends (or "heads") of those in thin walls, or in the outside of thick walls, being visible on the face.

Stretchers are bricks or stones which lie parallel to the length of the wall, those in the exterior of the work showing one side in the face of the wall.

The bricks or stones used for walling or arches should be well wetted before use, not only to remove the dust which would prevent the mortar from adhering, but also to prevent the bricks or stones from absorbing the moisture from the mortar too quickly. In building upon old or dry work, the upper surface should be swept clean and wetted before the mortar is spread upon it to form the bed for the new work. Brick or stone masonry should never be carried on while frost exists, or when it is likely to occur before the mortar is set. If it is necessary to go on with the work at such a time, it must be covered up with straw or boards every night.

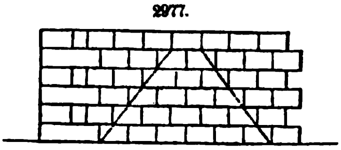
The parts of walls are as follows: *Footings* are projecting courses formed at the bottom of a wall, so as to distribute its weight over a large area. *Quoins* are the external angles or corners of buildings. A *coping* is a course placed upon the top of a wall to prevent wet from entering and soaking into the masonry. A *cornice* is a large moulded or ornamental course at the top of a wall, and is of the nature of a coping. The name is applied rather to the upper member of a principal wall in a building; whereas a coping generally surmounts a detached or less important wall. A *blocking course* is a course of stone placed on the top of a cornice to add to its appearance, and by its weight to steady the cornice and prevent its tendency to overbalance. A *parapet wall* is a low wall running along the edge of a roof-gutter or high terrace, to prevent people from falling over. A *balustrade* is a similar construction, but lightened by being broken into balusters. An *eaves course* is a projecting course formed under the lower edges of the slopes of a roof (the eaves), either merely for ornament, or to support a gutter. The *plinth* is a projecting base to a wall, intended to give an appearance of stability, and thus form an ornament. The *string course* is a horizontal course, generally of stone, carried round a building, chiefly for ornament. In many cases it is necessary to project certain courses of a wall beyond the face, in order to support wall-plates. This is done by *corbeling* or projecting each course beyond the one last laid.

I. Brickwork.—In order to obtain good brickwork the following points should be attended to: The bricks must be sound and well shaped. The mortar should be of good quality, carefully mixed, and used stiff. A good bond should be preserved throughout the work, both laterally and transversely. All bed-joints should be perpendicular to the pressure upon them; that is, horizontal in vertical walls, radial in arches, and at right angles to the slope of battering walls. In walling, the courses must be kept perfectly horizontal, and the arrises plumb. The vertical joints should be directly over one another; this is technically called "keeping the perpends"; if it is neglected, the courses are overrun and "bats" become necessary. The joints should all be full of mortar, close, well flushed up, and neatly struck or pointed as required. In good brickwork they should not exceed three-eighths of an inch in thickness, but with badly-shaped rough bricks the beds of mortar are necessarily made thicker, in order to prevent the irregularities of the bricks from bearing upon one another and causing fracture. Both bricks and mortar-joints should be of uniform size and quality in all parts of the work. Bricks are made of different sizes. The English standard is about 9 in. long, 4¼ in. wide, and 2½ in. thick. The American or Haverstraw standard is 8 in. long, 4 in. wide, and 2¼ in. thick. In nearly all cases bricks built in walling are laid upon their sides.

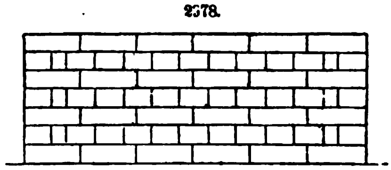
The thickness of a wall is the distance from one to the other face, and in this country is expressed in terms of inches of thickness, as a 6-in. wall, 12-in. wall, and so on. The English express it in terms of a brick.

Different Bonds.—*Heading bond* consists entirely of headers. As bricks vary in length more than

2977.



2978.



in any other dimension, their ends project unequally on the face, and it is difficult therefore to make neat work with this bond, especially in walls one brick in thickness. There is very little longitudinal strength in the wall, and the pressure on each brick is distributed over a comparatively small area (see Fig. 2977). Heading bond is chiefly useful in working round sharp curves, where the angles of stretchers would project too much unless cut off, and spoil the curve. When used in this position, the sides of the bricks must be roughly cut, so as to radiate from the centre of the curve. In walls of heading bond more than one brick thick, a line of bats or half-bricks must be introduced, in alternate courses, to form the transverse bond.

Stretching bond consists entirely of stretchers, and is adapted only for walls half a brick thick.

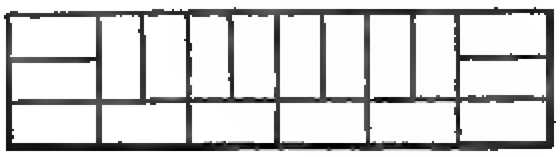
English bond shows, both on face and back, stretching and heading courses alternately, closers

being inserted as shown, and as before described, to give the lap (see Fig. 2978). This is the best bond for work generally. It gives the most simple combination for longitudinal and transverse strength. The number of stretchers is less in proportion as the wall grows thicker, being as follows:

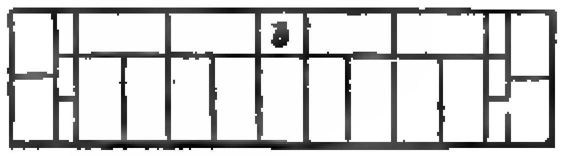
In a $1\frac{1}{2}$ brick wall the stretchers are one-half the number of the headers.
" 2 " " one-third " "
" $2\frac{1}{2}$ " " one-fourth " "
" 3 " " one-fifth " "

In English bond there are twice as many vertical joints in a heading as there are in a stretching course; therefore the vertical joints between the headers must be made thinner than those between

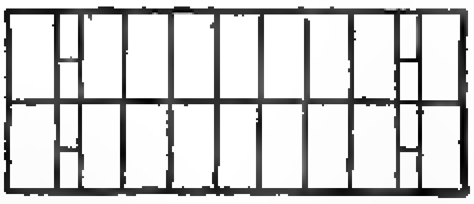
2979.



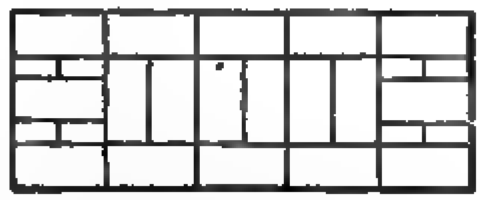
2980.



2981.



2982.



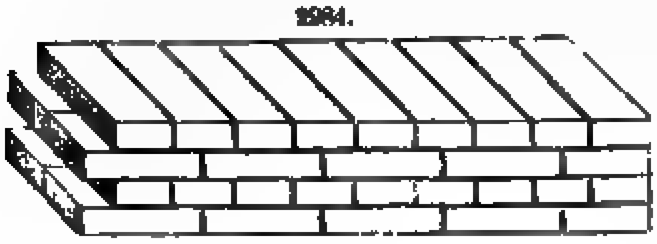
the stretchers; for if two headers were laid so as to occupy a greater length than one stretcher, the quarter-brick lap obtained by the aid of the closer would be encroached upon, and would soon disappear. Figs. 2979 to 2982 show the bond used for walls meeting at the ends to form a right angle, which is the most common case in practice. If, however, a wall is detached and terminated only by its ends being cut off square, as shown in these figures, the bond has to be slightly modified, so as to give the ends a neat finish.

2983.

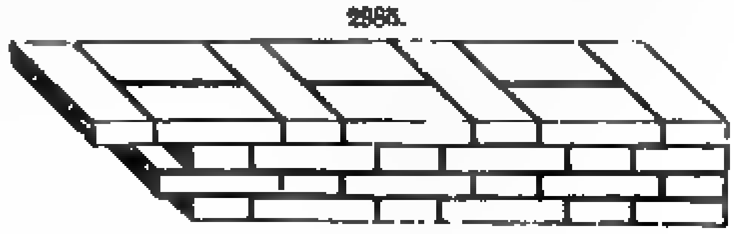
Section. *Elevation of Flemish Bond.*

Flemish bond shows in elevation (either on one or both faces of the wall, according to the variety of the bond adopted), in every course, headers and stretchers alternately; every header is immediately over the centre of a stretcher in the course below it; closers are inserted in alternate courses next to the corner headers to give the lap. The appearance of the face which distinguishes Flemish bond is shown in Fig. 2983. Double Flemish bond implies that both the front and the back of the wall are built in Flemish bond, presenting an

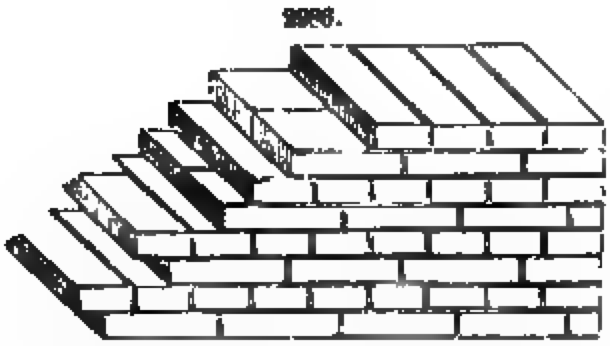
2984.



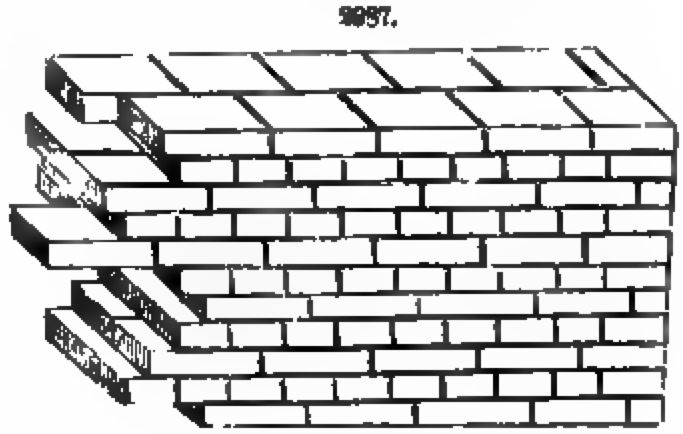
2985.



2986.



2987.



elevation like Fig. 2983 on both faces of the wall. Single Flemish bond consists of Flemish bond on one face of the wall, with English bond on the other.

Fig. 2984 is old English bond, or block bond; Fig. 2985, Flemish bond; Fig. 2986, cross bond; and Fig. 2987, combined cross and block bond.

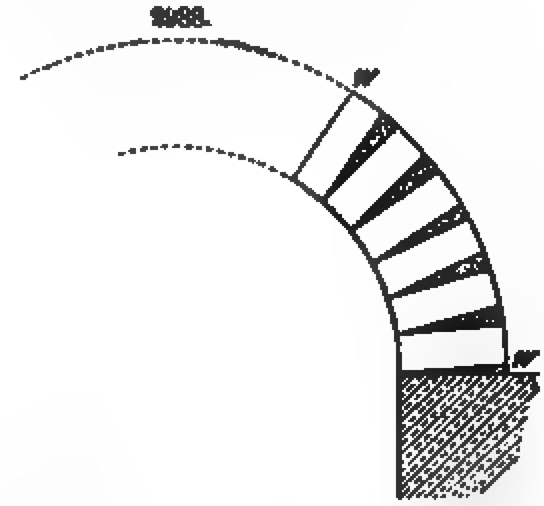
English bond is, upon the whole, to be preferred to Flemish bond for strength, as it contains a larger proportion of headers. The only advantage claimed for Flemish bond is its appearance, which is preferred by many, and has led to its use in brick buildings of a superior class. In 9-inch walls a

better face can be shown on both sides by Flemish than by English bond, as the unequal length of headers causes a rough face when there are many of them. In walls of $1\frac{1}{2}$ brick in thickness the strength is not so much impaired by using Flemish bond as it is in thicker walls. For thick walls English bond should be used if possible; but, if Flemish bond is required, it should have a backing of English bond, unless it is to show a fair face on both sides.

Bricks cut and rubbed to the exact shapes required, in order to get very fine joints, are frequently used in the "dressings" of brickwork, such as arches, quoins, etc.; this is termed "*gauged work.*" It is generally set in putty, and the joints do not exceed one-tenth to one-eighth of an inch in thickness.

Plain or rough brick arches are those in which the bricks are not cut or rubbed so as to form voussoirs accurately radiating to a centre. The joints are therefore wider at the "extrados" than they are at the "intrados." Such arches are used for ordinary brickwork in tunnels and concealed work generally. Rough arches of small span are generally turned in half-brick rings, $4\frac{1}{2}$ in. thick, as shown at *h h* in Fig. 2988. In arches of quick curve, with not more than 3 or 4 ft. radius, this is absolutely necessary to prevent very large joints at the extrados. Fig. 2988 is the section of portions of small arches, of which one, *w w*, is turned in 9-inch rings consisting of headers. It will be seen that the mortar-joints in this are much wider at the extrados than those of the portion *h h*, built in rings half a brick in thickness. *Rough-cut or axed arches* have the bricks roughly cut with a bricklayer's axe to a wedge form, and are used over openings when the work is to be plastered, as relieving arches at the back of window- and door-heads, or as face-arches in work of an inferior description. *Gauged arches* are built with bricks accurately cut, and rubbed down so as to radiate from the centre. They are used chiefly for external face-arches over openings and recesses in superior work.

2988.



II. Masonry.—Masonry may be classed either as "ashlar" or "rubble." *Ashlar* is built from large blocks of stone, carefully worked, while *rubble* is composed of small stones, often irregular in shape, and in the roughest description hardly worked at all. Between these two there are many gradations. Different kinds of masonry are sometimes combined. Thus, walls are built with ashlar facing and rubble backing, or even with stone facing and brick backing.

Masonry requires more skill to build than brickwork. The bricks, being all the same size, are laid according to regular rules; whereas with each stone judgment is required, in order that it may be laid in the best way. The higher the class of work the more regular are the stones, and the more easily are they built. As a rule every stone in ordinary walls and arches should be laid upon its "natural bed;" that is to say, the bed upon which it rested when in the quarry should now be perpendicular to the principal pressure upon it. When a stratified stone is placed vertically, and so that the layers of which it is composed are parallel to its face, they are apt to be split off in succession by the action of the weather. Moreover, a stone in this position has not so much strength to resist crushing as it has when placed on its natural bed. In a cornice with overhanging or undercut mouldings, the natural bed should be placed vertically and at right angles to the face; for if placed horizontally, layers of the overhanging portions will be liable to drop off. There are other exceptions to the general rule which occur in more elaborate work; also some dependent upon the nature of the stone, the quarry, etc.

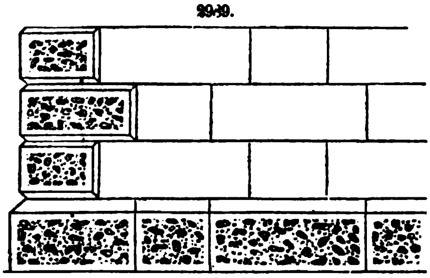
Great attention should be paid to the bond in all kinds of masonry. On the face the vertical joints should break upon every stone, no straight joints being allowed. The bond across the thickness of the wall is of still greater importance. Either "thorough bonds," extending from one face to the other, should be inserted at regular intervals, or "headers" should cross each other alternately from opposite sides, extending inward about two-thirds the thickness of the wall. Some authorities prefer headers to thorough bonds in walls more than 3 ft. thick, because the interior of the wall settles down rather more than the sides, leaving a hollow, so that a thorough bond-stone would be unsupported in the middle, and might be broken. Another reason against long bond-stones is, that there is danger of the beds not being evenly worked throughout; in which case the pressure comes upon a few points and the stone is liable to break in two. Masons are very apt to build up the sides of a wall separately, filling in with small stuff, or even dry packing. The wall thus consists of two thin slabs, united only by the thorough bonds. This should never be allowed. The stones should be made to cross from opposite sides of the wall, and overlap as much as possible, so as to assist the bond-stones in giving transverse strength to the wall. The interior of walls of every description should be solidly filled in, every stone being bedded in mortar, and all interstices flushed up. Thorough bonds should always be amply thick enough to carry the weight above them, as, if broken, the fracture forms a dry joint, and they become worse than useless. The width of bond-stones may be about $1\frac{1}{2}$ time their height, and the aggregate surface shown by their ends, on each face of the wall, should be from one-eighth to one-quarter of the area of the face. Care should be taken that each bond-stone is of sufficient sectional area throughout its length.

Ashlar Masonry is built with blocks of stone very carefully worked, so that the joints generally do not exceed one-eighth or one-tenth of an inch in thickness. The size of the blocks varies with the nature of the stone, and must also be regulated according to the facilities that are available for mov-

ing and setting them. The following is Rankine's rule for the proportion of stones: "In order that the stones may not be liable to be broken across, no stone of a soft material, such as the weaker kinds of sandstone and granular limestone, should have a length greater than 3 times its depth. In harder materials the length may be 4 or 5 times the depth. The breadth in soft material may range from 1½ time to double the depth; in hard materials it may be 3 times the depth." Ashlar is the most expensive class of masonry built, and depends for its strength upon the size of the stones, the accuracy of the dressing, and the perfection of the bond, but hardly at all upon the quality of the mortar. The mortar used for the superior descriptions of ashlar must be very fine, and free from grit. The outer portion of the joint, about three-fourths of an inch in from the face, is generally filled with putty—either that formed from lime and water, and known as "plasterer's putty," or in some districts glazier's white-lead putty is used. The faces of ashlar stones may be polished, worked in any way, or left rough; but a drafted margin* is generally run round them to insure accuracy in setting and fitting the stones. The joints, though very carefully dressed, should not be too smooth; otherwise their surfaces will afford no key for the mortar, nor offer sufficient resistance to the sliding of the stones. It is important, however, that the surfaces of each stone should be "out of winding," that is, true planes, and that they should be square to one another; and great care must be taken that bed-joints are not worked hollow. Where the beds and joints are not carefully worked throughout, they should be so for at least 6 in. in from the face.

The lap or bond given to the stones varies, according to the nature of the work, from once to once and a half the depth of the course; and it should under no circumstances be allowed to be less than from 4 to 6 in., according to the size of the stones. The best bond for ashlar consists of headers and stretchers alternately on the same course—an arrangement similar to Flemish bond in brickwork (see Fig. 2983). In setting ashlar, the stone should first be placed in position dry, to see if it will fit. The upper surface of the last course should then be thoroughly cleaned off and wetted; on this a bed of mortar is evenly laid, with a strip of putty about three-fourths of an inch wide along the front edge. The block, with its bed-joint well cleaned and wetted, is then laid evenly in its place, and settled by striking it with a mallet.

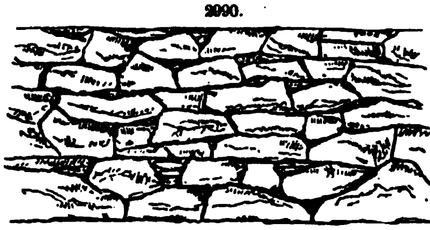
2989.



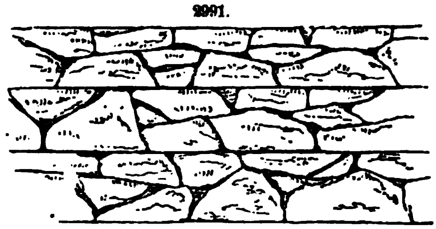
Ashlar walling is described as "coursed" or "random." Coursed ashlar walls consist of blocks of the same height throughout each course. This is the most usual form in which ashlar is built, but it is the most expensive, as great waste of material and labor is occasioned by reducing all the stones to the same height. Fig. 2989 shows coursed ashlar walling, with chamfered and rusticated quoins and plinth. Random ashlar walls are built with rectangular blocks of all sizes and dimensions. This is a cheaper kind of work, as it enables a larger proportion of the stone as quarried to be used without waste in reducing to fixed sizes; but it is generally considered inferior in appearance to coursed work, and is very seldom adopted.

Rubble.—There are several kinds of rubble work, each known by a technical name, depending upon peculiarities in the arrangement of the stones, or in the work upon them. In common random rubble work, uncoursed, Fig. 2990, the beds and joints are not dressed, projecting knobs and corners are knocked off with the hammer, and the stones lie together at random, the interstices being filled in with small spalls and mortar. No attention is paid to courses, though each stone should be approximately horizontal. This is a most inferior description of walling, unless it is executed with very good mortar, upon which its strength greatly depends. In random rubble built in

2990.



2991.



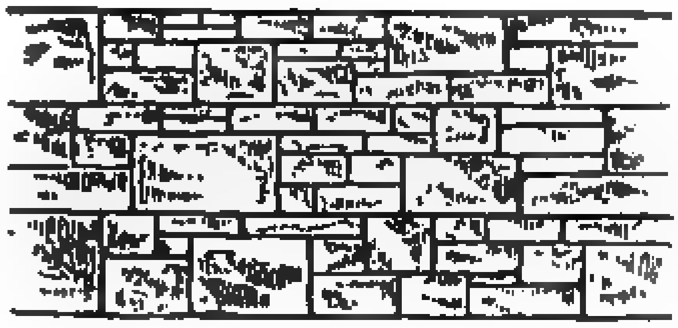
courses (Fig. 2991), the work is brought to a level throughout its length at about every 12 or 14 in. in height, so as to form courses of that depth. The work in each course is built random, and may consist of two, three, or more stones in depth, pinned in with spalls as before described. Squared rubble, uncoursed, Fig. 2992, has the joints and the angles of the faces neatly squared with the tools locally used. The beds are horizontal, and the side joints vertical. This description of rubble is peculiarly adapted for such stones as have a fine cleavage, affording bed-joints which require little or no working. Squared rubble built in courses, Fig. 2993, is squared rubble brought to a level course throughout its length at every 10 or 14 in. in height; it is sometimes known as "irregular coursed rubble brought up to level courses." Coursed header work is rubble similar to that shown

* "Drafted margins," or "drafts," are narrow strips or borders chiseled round the edges of the faces of a stone to enable it to be set with accuracy, and to improve its appearance.

in Fig. 2993, except that the headers or bond-stones are each of the full depth of the course in which they occur, the intervals between them being filled in with smaller stones. Coursed rubble, or regular coursed rubble, Fig. 2994, consists of stones laid in courses, every stone in the same course being of the same height; the height of the courses may, however, vary from 4 to 8 in. Dry rubble is rubble (generally "random") built without any mortar. It is the cheapest form of work, but requires considerable skill on the part of the builder. Flint rubble is composed of flints and pebbles

2992.

2993.

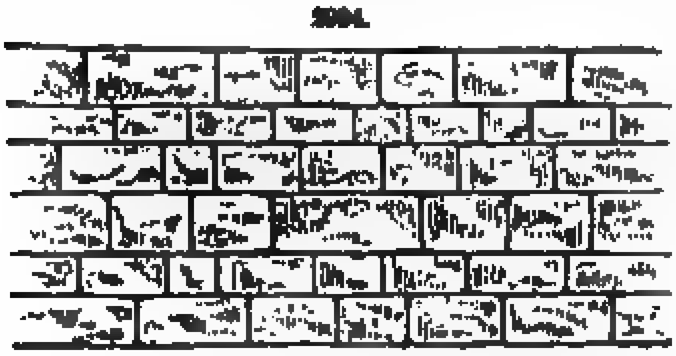


laid in mortar. It forms a kind of concrete depending upon the mortar for cohesion. Great care must be taken to keep it dry and safe from the action of frost. The interior of the wall is sometimes filled in with chalk, broken bricks, pebbles, etc.

Block in course, or blocked course, Fig. 2995, is a name given to a class of masonry which occupies an intermediate place between ashlar and rubble. The stones are of large size, so that they must be procured in blocks, not as rubble; but the beds and joints are only roughly dressed, and so the work cannot be described as ashlar. This kind of walling is sometimes known as "hammer-dressed ashlar." It is used chiefly in engineering works, and seldom, if ever, for ordinary buildings.

Cut-Stone or Ashlar Arches.—In block-stone arches the voussoirs are always cut to a wedge shape. The curve of the arch having been set out full size on a board, and the number of stones and thickness of arch having been decided, the intrados is divided into as many parts as there are stones, and lines drawn from the centre through these points, till they cut the extrados, give the sides of the voussoirs. By the aid of the diagram thus laid out, patterns or templets in wood or zinc are made

2994.



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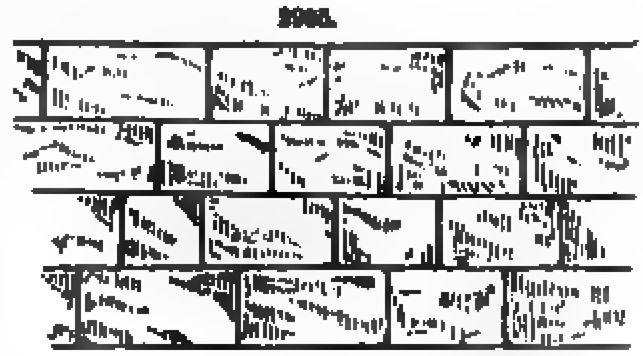
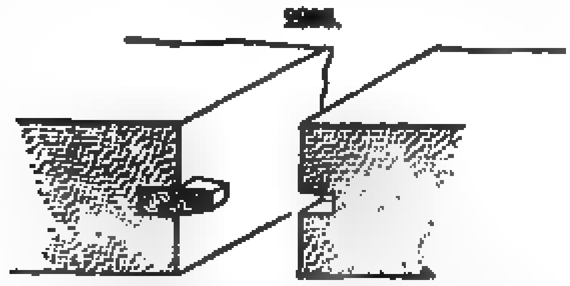


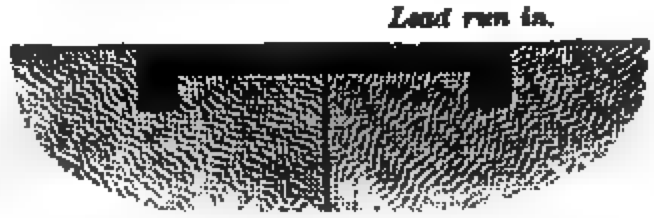
for the use of the stone-cutters, who are thus enabled to work the stones to the required forms. In setting stone arches, the space to be occupied by each voussoir—not forgetting the thickness of the joints—is carefully laid out on the centre, and the position of the stones checked as they are set. The stones should be set alternately on each side of the centre, so as to weight it evenly. The keystone should be carefully fitted at the last before it is set, and driven gently into its place with a few taps of a mallet. When the arch is so long in plan that one stone cannot extend through from front to back, the work must be built with a regular bond along the soffit. The voussoirs are kept at the same width all through, but of different lengths, so as to break the bond in the length of the arch. Rubble arches are built of smaller stones, generally roughly dressed to the wedge shape. They should be built in mortar of good quality, as they depend greatly upon its coherence for their strength.

Joints and Connections.—There are several methods of giving additional strength to the joints of masonry, the most common of which will now be considered. With regard to metal connections, it may be said, once for all, that copper and bronze make the best, as they do not oxidize to any great

2996.



2997.



extent. If iron is used, it should be well protected from air or moisture, and also painted or galvanized, or it will rust, increase in bulk, and split the stones. All metals are liable to do the same, more or less, by their expansion and contraction under heat and cold. Doweled joints are formed with slightly tapering pins, or "dowels," which fit into holes made in the stones opposite to one another (see Fig. 2996). The dowels may be rectangular, square, or circular in section, and formed

of hard stone, slate, or metal. Joggled joints are similar to doweled joints, except that the joggle or projection is a part of the stone, instead of being detached like the dowel. In grooved and tongued joints, a prolonged joggle or tongue is worked upon one stone, and fits into a groove in the other. A similar joint is used in joinery. Metal cramps are generally placed in a channel cut in the upper surface of two stones, having sinkings at the ends, into which the turned-down extremities of the cramp may fit. The channel should be deep enough to conceal the cramp, and is filled in with lead or cement to protect the latter from oxidation (see Fig. 2997). (See STONE-CUTTING MACHINERY, and STONE-CUTTERS' TOOLS.)

MASS. See DYNAMICS.

MEASURING AND WINDING MACHINE. See CLOTH-FINISHING MACHINERY.

MECHANICS is that branch of natural philosophy or physics which treats of the action of forces on bodies. It is commonly considered under the subdivisions of STATICS, DYNAMICS, HYDROSTATICS, and HYDRODYNAMICS, which see. The following references include the principal encyclopædias, treatises, etc., on both the theory and application of the science:

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MELODEON. See ORGANS, REED.

MERCURY-GAUGE. See BOILERS, STEAM.

METER, GAS. See GAS, ILLUMINATING, APPARATUS FOR.

METER, WATER. See WATER-METER.

METRIC SYSTEM. A system of weights and measures, according to which the ten-millionth part of a meridional quadrant of the earth is the unit of length, said unit being termed the metre (*mètre*). It is commonly taken as equal to 39.37079 inches, though according to accurate observations at the Ordnance Survey Office in Southampton, England, it is found to be 39.37043 inches. The decimal multiples and subdivisions are indicated by prefixes placed before the names of the unit. The prefixes denoting multiples, derived from the Greek, are *deca*, ten; *hecto*, hundred; *kilo*, thousand; and *myria*, ten thousand. Those denoting subdivisions are taken from the Latin, and are *deci*, tenth; *centi*, hundredth; and *milli*, thousandth. The following table gives the values of subdivisions and multiples of the metre in English inches and yards:

MEASURES.	In English Inches.	In English Yards.
Millimetre	0.03937	0.0010936
Centimetre	0.39371	0.0109363
Decimetre	3.93708	0.1093633
Metre	39.37079	1.0936331
Decametre	393.70790	10.9363310
Hectometre	3,937.07900	109.3633100
Kilometre	39,370.79000	1,093.6331000
Myriametre	393,707.90000	10,936.3310000

Unit of Surface.—The unit of surface measure is the *are*, equivalent to the square of 10 metres. More commonly, however, the terms square metre, square centimetre, etc., are employed. 6.4513669 square centimetres = 1 square inch; 9.2899683 square decimetres = 1 square foot; and 0.83609715 square metres = 1 square yard.

Unit of Capacity.—This is the cube of a tenth part of the metre, and is called the *litre*, or cubic decimetre. It is equivalent to 1.7607 English pint, or 61.027052 cubic inches. 1 cubic inch = 16.386175 cubic centimetres. The unit of capacity when referred to solidity is the cubic metre, or *stère*.

Unit of Weight.—This is the weight of that quantity of distilled water at its maximum density (4° C.) which fills the cube of the hundredth part of a metre, and is called the *gramme*. A cubic

metre of water is a *tonne*, a cubic decimetre a *kilogramme*, a cubic centimetre a *gramme*, and a cubic millimetre a *milligramme*. The following table shows the value of metric weights in English grains and pounds:

WEIGHTS.	In English Grains.	In Lbs. Avoirdupois. 1 lb. = 700 grammes.
Milligramme ($\frac{1}{1000}$ part of a gramme)................	0.015432	0.0000022
Centigramme ($\frac{1}{100}$ " ")................	0.154323	0.0000220
Decigramme ($\frac{1}{10}$ " ")................	1.543235	0.0002205
Gramme................	15.432349	0.0022046
Decagramme (10 grammes)................	154.323488	0.0220462
Hectogramme (100 ")................	1,543.234880	0.2204621
Kilogramme (1,000 ")................	15,432.348800	2.2046218
Myriagramme (10,000 ")................	154,323.488000	22.0462126

The Unit of Mechanical Work in this country is the foot-pound—that is, the force necessary to raise one pound weight one foot above the earth in opposition to the force of gravity. A horse-power is equal to 33,000 lbs. raised to the height of one foot in one minute of time. In France the *kilogrammètre* is the unit of work, and is the force necessary to raise one kilogramme to a height of one metre against the force of gravity. One kilogrammetre equals 7.233 foot-pounds. The *cheval-vapeur* is nearly equal to the English horse-power, and is equivalent to 32,500 lbs. raised to a height of one foot in one minute of time. The force competent to produce a velocity of one metre in one second in a mass of one gramme is sometimes adopted as a unit of force.

Units of Heat.—These units vary. The French unit of heat, called a *calorie*, is the amount of heat necessary to raise one kilogramme (2.2046213 lbs.) of water one degree centigrade in temperature; strictly, from 0° C to 1° C. In this country we sometimes take one pound of water and one degree Fahrenheit as the unit; sometimes one pound of water and one degree centigrade.

Works for Reference.—"The Metric System," Barnard, New York, 1871; and reports of the Warden of the Standards (London), of which the 7th, 8th, and 9th (1872-'75) are very interesting and valuable. See also "Comparisons of Standards of Length made at the Ordnance Office, Southampton," by Capt. A. R. Clarke, 1866, and "Report of the British Standards Commission on the Metric System," 1869.

MICROPHONE. An instrument which greatly magnifies weak sounds through the action of the sonorous vibrations in varying the force of an electric current. In simple form it may consist of a rod of gas-carbon, *A*, Fig. 2998, set in supports *C C* of the same material, the latter being connected with the wires *x y* in communication with the battery *B*. The wires are connected with a telephone. By this simple device sounds entirely inaudible to the unaided ear can be easily heard. So sensitive is the instrument that a slight touch on the board which supports the carbon pencil, or a mere rub with the soft part of a feather, is distinctly heard at the receiving station. The movement of the softest part of a camel's-hair brush on any part of the board is distinctly audible. If held in the hand several feet from a piano, the whole chords—the highest as well as the lowest—can be distinctly heard at a distance. The tick of a watch, the beating of a pulse, or even the tramp of a fly, can thus be made audible a hundred miles distant from the source of sound.

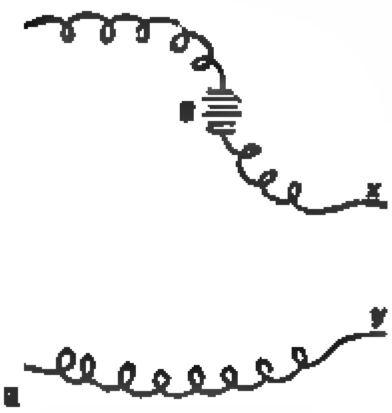
The cause of this remarkable phenomenon is due to the differences in electrical resistance of the carbon pencil; and these differences are owing to the fact that the substance of the body, under the influence of sound-waves, increases and diminishes in size at all points in the centre as well as at the surface, exactly in accordance with the sonorous wave by which that variation has been produced. As the body is a conductor and placed in light contact with another conductor, forming thus a part of a voltaic circuit, an undulatory character is given to the electrical current, which is reconverted into sonorous vibrations by means of a suitable receiver, such as the Bell telephone. (See TELEPHONE.) To illustrate, if we assume a line of molecules at the point of contact of the minute masses of conducting matter in their neutral condition to be arranged as shown in Fig. 2999 at *A*, they will appear under compression as at *B*, and under dilatation as at *C*. In the former case the electrical resistance would be less, and in the latter case more, than in the normal condition. Hence we should get variation in their electrical resistance, and thus sonorous waves would vary the strength of an electric current; and consequently, as already stated, the variations of the electric current can be made to reproduce sonorous vibrations.

For the carbon pencil a variety of other substances may be substituted. Sound is transmitted by any electrical conductor, provided one or more portions of it are separated and brought into contact only by a slight but constant pressure. Thus, if the ends of a wire terminating in two common nails laid side by side, and separated from each other by a slight space, are electrically connected by laying a similar nail between them, sound will be reproduced. The effect is improved by building up the nails log-hut fashion into a square configuration, using 10 or 20 nails. A piece of steel watch-chain acts well. All metals can be made to produce identical results, provided the division of the metal is small enough, and that the material used does not oxidize by contact with the air filtering through the mass. Thus platinum and mercury are very excellent and unvarying in their results, while lead soon becomes of such high resistance, through oxidation upon the surface, as to be of little or no use. A mass of bright round shot is peculiarly sensitive to sound while clean; but as the shot soon becomes coated with oxide, this sensitiveness ceases. Carbon again, from its surface being entirely free from oxidation, is excellent; but the best results have been obtained from mercury in a finely divided state. For this purpose a comparatively porous non-conductor, such as the willow charcoal used by artists for sketching, is heated gradually to a white heat and then suddenly plunged into mercury. The vacua in the pores caused by the sudden cooling become filled with innumerable minute globules of mercury, thus, as it were, holding the mercury in a fine state of

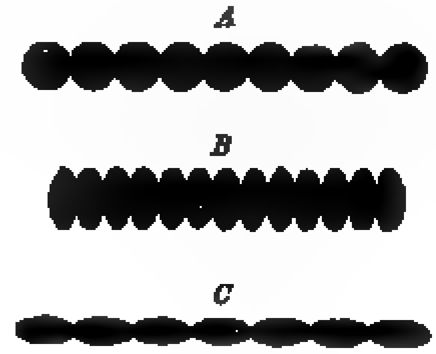
division. Carbon treated in a similar manner, with and without platinum deposited upon it from the chloride of platinum, has been used. Similar effects have been obtained from the willow charcoal heated in an iron vessel to a white heat, and containing a free portion of tin, zinc, or other easily vaporized metal. Under such conditions the willow carbon will be found to be metalized, having the metal distributed throughout its pores in a fine state of division. Iron also seems to enter the pores if heated to a white heat, without being chemically combined with the carbon as in graphite; and, indeed, some of the best results have been obtained from willow charcoal containing iron in a fine state of division.

Numerous efforts have been made to construct a receiving microphone, in order to dispense with the use of the telephone altogether. The first device of this kind was that of Mr. James Blyth, who used a small glass jar containing common cinders broken into coarse fragments; a piece of tin plate was passed down on each side of the jar between the glass and the cinders, and to these tin slips

2998.



2999.



were attached wires by which the apparatus was connected to a similar arrangement in another room, a couple of Grove's cells being included in the circuit. With this simple apparatus—that is to say, two glasses filled with cinders connected with one another and with a voltaic battery of two Grove cells—Mr. Blyth states that "articulate sounds uttered in one cinder jar were distinctly heard in the other, and even voices could be distinguished." (See *Engineering*, xxv., 12.) Another device, proposed by Mr. W. J. Millar, consists of an ordinary horse-shoe permanent magnet, around one of the limbs of which is wound lengthwise from two to three yards of insulated copper wire (No. 30 B. W. G.). Against the magnet so wound is placed the lid of a tin box, and with this simple apparatus Mr. Millar states that "tuning-fork sounds, singing, whistling, speaking, and violin music were heard distinctly." In using this instrument, it is placed in circuit with a transmitting microphone and with a single Leclanché cell. (See *Engineering*, xxv., 502.) Professor Hughes has also devised a receiving microphone, which is constructed on the theory that if the action of sonorous vibrations upon certain parts of an electrical circuit be to vary the dimensions of those parts, it is fairly reasonable to expect that a corresponding variation of those dimensions could by suitable apparatus be reconverted into undulations of sound; and again, if it be true that the mechanical variations give to an electrical current an undulatory character, why may it not be supposed that the transmission of a powerful undulatory current of electricity through a similar circuit would produce a mechanical variation capable of setting a membrane or other acoustical instrument into vibration, and so imparting to the air a series of waves of sound? Referring to Fig. 3000, A is a small hollow cylinder of tin plate, closed at one end by the membrane $N\,N$ of parchment stretched over it like the head of a drum. To the centre of the membrane is attached a small block of pine P, which carries the slip $B\,P$, also of the same material, the block being of sufficient thickness to cause the farther end of the slip to be clear of the edge of the drum, so that the whole of the rest of the apparatus is supported solely by the centre of the membrane. Upon the slip of pine $B\,P$ is fastened one of Professor Hughes's articulating microphones, having a lever of brass L pivoted at its centre of gravity between two supports, and carrying at one end a small slab of prepared pine charcoal C, which is maintained by the spiral spring S at a constant pressure against a similar slab of charcoal below it, the latter being attached to the slip of pine $B\,P$. The degree of pressure between the slabs of charcoal may be regulated by turning the milled head M, whereby the tension of the spring may be varied by winding up or easing off a silk thread attached to one end of the spring. To the lever L and upper slab C is attached the wire x, and to the lower carbon is connected the wire y, by which the instrument is placed in circuit with the transmitting apparatus. It will be observed that the principle of action, according to the theory given, is that the carbon blocks at C are, under the influence of an undulatory electric current flowing through them, thrown into a state of mechanical vibration, not unlike that produced by the celebrated Trevelyan experiment (in which sound is produced by what may be called an undulatory current of heat), and this vibration is rendered audible by a series of little blows upon the membrane to which the apparatus is attached, and the sound so increased is again still further reinforced by the resonating cavity over which the membrane is stretched.

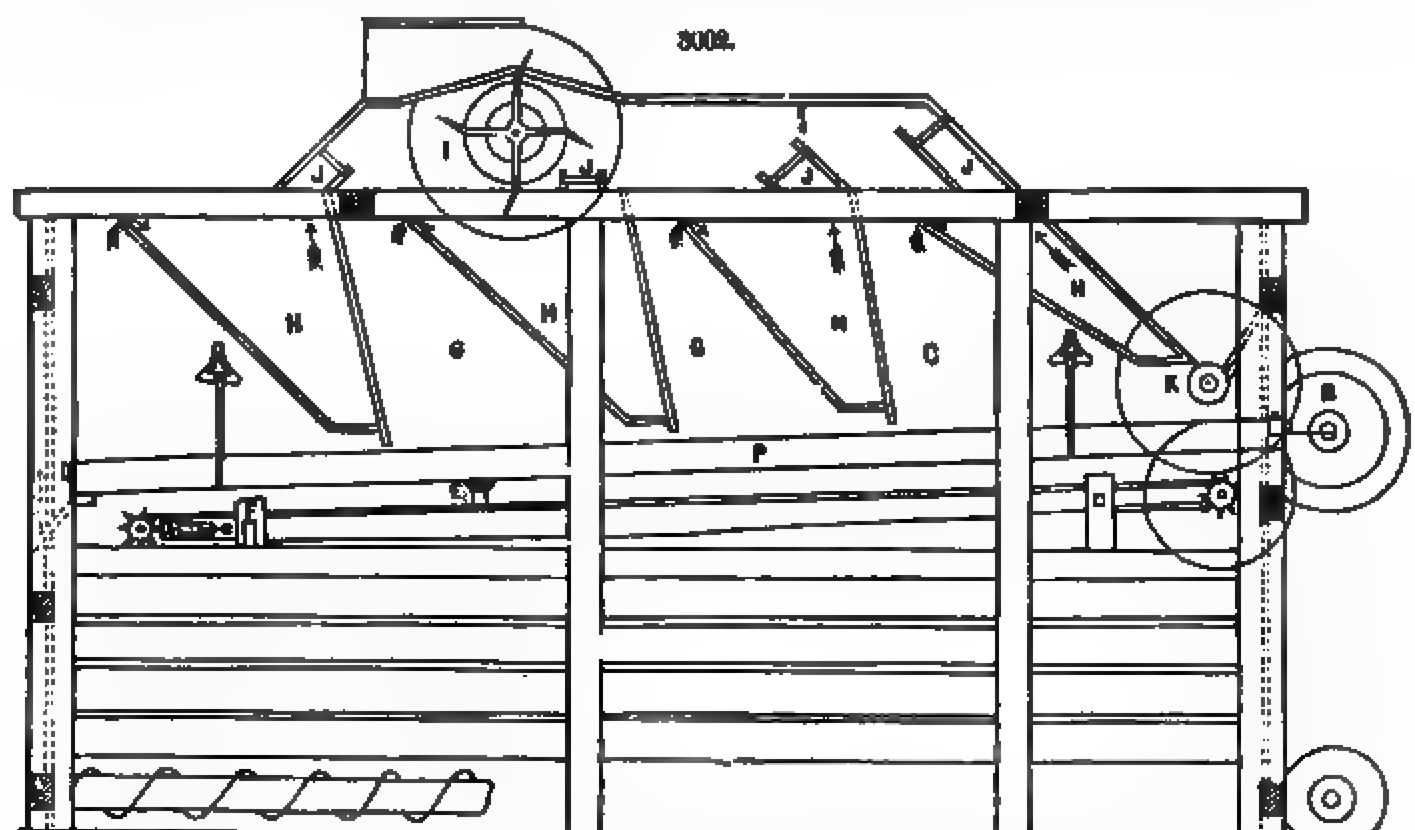
Three inventors claim the origination of the microphone—Professor D. M. Hughes, Dr. T. A. Edison, and M. Clérac. The discussion of their rival claims will be found in the files of *Engineering*, *The Engineer*, and the *Scientific American* for 1878. See also these journals for reports of experiments on the microphone. Numerous modifications of the instrument will be found described in the *Scientific American Supplement*, No 163.

MIDDLINGS-PURIFIERS. Apparatus for cleansing the intermediate product of ground wheat termed *middlings*, and separating it from bran on the one hand and fine flour on the other. There are a very large number of patents on these machines, for most of which see "Digest of Middlings-Purifiers," De W. C. Allen, Washington, 1878. The type of purifier here described exhibits the essential features of the apparatus, and is one which has given good results under practical test.

Fig. 3001 represents a perspective view, and Fig. 3002 a vertical sectional view, of a large-sized machine. The middlings are received in the hopper over the feed-roll *K*, Fig. 3002, and by this roll are delivered to the sieve *P*. *G G G G* are air-chambers over the sieve. *H H H H* are pockets or deposit chambers. *J J J J* are valves or dampers to regulate the force of the air-current. *I* is a suction-fan. *E* is a brush worked automatically on the lower side of the sieve. There are windows opening into the air-chambers for convenience in observing the material while being operated upon. The sieve *P* is divided into sections corresponding with the air-chambers *G G G G*, each section being covered with bolting-cloth, differing in fineness, the finest being on the section at the head or receiving end of the sieve, and the coarsest on the section at the tail of the sieve. The sieve receives a reciprocating motion from the eccentric *B*. The fan *I* produces an air-current upward through the bolting-cloth into the air-chambers *G G G G*, following the bent arrows into the pockets *H H H H*, through the openings *J J J J*, to the fan, and thence into the dust-room. The middlings are delivered to the head or receiving end of the sieve by the feed-roll in a thin and uniform sheet. The receiving end being the highest, the middlings move gradually toward the lower or discharging end; and as the finest cloth is placed at the head, the finest portion of the specks are taken out at the first section by a light draught of air, while the purified fine middlings are sifted through; coarser and heavier specks and particles of bran are drawn out at the second section by means of a stronger draught of air, and the bolting-cloth on this section being coarser, larger and coarser middlings are sifted through,

3001.

3002.



and so on until the last section is reached, where, the finer middlings having been previously separated from the coarse middlings, and the latter only remaining, a very coarse cloth can be used and a very strong draught of air applied. The conveyers below the sieve are supplied with the necessary cut-offs for disposing of the middlings in grades or in bulk, as may be deemed advisable, and for returning such portions as may require further action of the air. Each transverse partition between the air-chambers has a piece of ticking, extending from its lower edge to the surface of the sieve, so that the air-current from each chamber is distinct and independent. The air-current through the

bolting-cloth and the middlings upon it is considerably stronger at the surface of the middlings than it is immediately above them; hence, specks of bran, etc., raised from the middlings by the current, will be liable to drop back again. This difficulty is avoided by the converging wing-boards forming the lower sides of the pockets. This device reduces the air-chamber upward, and after particles of bran and specks leave the cloth or surface of the middlings, their movement becomes constantly accelerated until they are discharged through the throat, shown by the bent arrows in Fig. 3002, into the pockets. The brush *E*, Fig. 3002, extends across the width of the sieve underneath, and travels its entire length from head to tail. It is mounted on an endless chain, and travels in one direction on ways and around pulleys, as shown.

A double machine may be used, and is designed for mills where the amount of middlings is too large to be conveniently handled by passing the whole body over one sieve. Its construction differs from that of the machine already described in having two or more reciprocating sieves, each sieve covered with cloth differing in fineness, with a grading-reel arranged across the head of the sieves. This grading-reel in a double machine is covered with two grades of bolting cloth: the first half with a cloth whose meshes allow the fine middlings to pass through upon the head of the first reciprocating sieve; the last half with a cloth of coarser mesh to allow the coarse middlings to pass through upon the second reciprocating sieve. The fine middlings are therefore passed upon the sieve having the fine cloth, and the coarser middlings upon the sieve having the coarse cloth. A longitudinal partition runs the whole length of the machine, dividing the air-chamber into compartments corresponding to the width of each sieve. Two or more machines can be combined in this way, and the grading-reel can in some instances be dispersed with, the separating-reel in the mill being used to accomplish the same purpose. It is desirable, however, always to use a large or long machine where a given amount of bolting or sifting surface is required, rather than divide the same into two or more short machines, because when a body of middlings is placed upon a reciprocating sieve, the motion of the sieve causes the light material and refuse in the middlings to separate and rise to the surface. This separation aids materially in the thorough purification of the middlings by the air-currents. The greatest benefit to be derived from this separation cannot be reached until the material has passed over some considerable portion of the bolting surface. Therefore, to continue them while in this condition on the same sieve must give better results than could be reached by once or more times mixing the material, as must be done while passing it from one sieve to another. The use of a large machine also avoids more or less expense in elevators, conveyers, etc., made necessary by increasing the number of the machines. H. L. B.

MILK-CAN. See Dairy Apparatus.

MILK-COOLER. See Dairy Apparatus.

MILKER. See Agricultural Machinery.

MILK-PAN. See Dairy Apparatus.

MILLING, GRAIN. It is probably true that the American new process of milling was made practicable by the introduction of the middlings-purifiers (which see) as invented by William F. Cochrane, the Supreme Court of the United States having given a decision in favor of the patents of that inventor. Before the date of the Cochrane inventions, which were made shortly before 1863, there were two modes or processes in use for manufacturing flour from wheat, one practised in this country and the other in Europe. Before the wheat was subjected to either process, it was properly cleaned by various machines, such as winnowing machines, screens, smut machines, and scourers, the practical effect of which was to rid the grain as much as possible of such impurities as were mechanically mixed with the sound grains of wheat, and such as adhered to their exteriors. According to the American process, which has of late years been called low milling, the cleansed wheat was ground directly by millstones sufficiently fine to separate practically all the flour-producing portions of the grains or berries from the colored skins or cuticles, and the resulting meal, or chop, was subjected to the operation of bolts, which permitted the fine flour, commonly called superfine flour, to pass through, but retained the coarser portions of the meal or chop, including both such flour-producing portions as were not ground fine enough to pass as flour and the colored matter resulting from the action of the millstones upon the skins of the grains. This mixed mass passed out at the lower end or tail of the flour-bolts, and constituted what is commonly called tailings. These tailings were then subjected to the action of a second sifting machine or series of sifting machines, having meshes progressively increasing in size, the result of the operation being the division of the mass into portions of different coarseness. The coarser portions resulting from this division consisted almost wholly of the disintegrated skins of the wheat-grains, and constituted what are called collectively offal, and by various other names appropriated to the degrees of coarseness, such as bran, fine bran, and shipstuff. The finest product of the division of tailings above mentioned was a mixture of such coarser flour-yielding portions of the wheat-grains as were not fine enough to pass through the first bolts as flour, and of such portions of the ground skins of the wheat-grains as were of about the same fineness as such coarser flour-yielding portions, with which were mingled more or less of fine particles of flour, which were not bolted out by the previous operation of bolting. This mixture was called middlings; and by reason of being composed in part of ground portions of the skin of the wheat, it had a brownish color. As these middlings, although as a whole brown in color, contained much valuable flour-yielding material, it was customary to regrind and rebolt them to recover the resulting flour. But inasmuch as the middlings contained light pulverulent impurities, and also fine portions of the colored skin of the wheat-grains, the grinding of the mass had the effect to reduce a large portion of these last to fine powder, so that when the rebolting took place the resulting flour was discolored or specked with fine bran, instead of being white; and the flour obtained was not only inferior in color, but was contaminated in quality by the presence of the pulverulent impurities and specks or fine portions of the skin of the grains. Sometimes this middlings-flour was kept separate from the superfine flour, and sometimes it was mixed with it; but in either case the practical

result of the American system of low milling was the production of more or less flour specked with fine particles of bran or the skin of the wheat.

According to the European process, which may be called high milling, the cleansed wheat was subjected to a series of successive grinding operations, generally four or five, alternated with a corresponding series of cleansing operations; the object and effect attained by the successive grinding operations being to detach the skin of the grains as much as possible from the flour-yielding portions before the latter were ground sufficiently fine to make superfine flour, and then to grind these latter portions as free as possible from mixture with portions of the skins; while the object and effect of the alternated cleansing operations was to save such flour-yielding portions as were incidentally reduced to powder, and to remove the detached portions of the skins of the grains from the mass to be reground after each successive cleansing. The alternated cleansing operations were effected by currents of air which carried off the bran-flakes from the more heavy flour-yielding portions. The result of the process was flour practically free from specks of bran; but this flour was obtained by a prolonged and complex series of operations.

The object of the Cochrane improvement in the art is to obtain flour practically free from light pulverulent impurities and specks of bran without the tedious and complex series of operations constituting the European process, or in other words to obtain flour which is practically as good as that produced by the European system of high milling with the simplicity and directness of the American system of low milling; and his improvement appears to be based upon the discovery that the light impurities and speck-producing matter of wheat can be separated from the flour-yielding portions *after* the wheat has been ground sufficiently fine to detach the last from the first two, as distinguished from the practical separation of the speck-producing matter of the wheat from the flour-yielding portions *before* the latter are ground to the fineness of flour. In carrying this invention into practical effect, Cochrane dispensed with the multiple grindings of the European system of high milling on the one hand, and, on the other hand, superadded to the direct American system of low milling a purifying operation, intermediate between the removal of the fine flour from the meal or chop and the regrinding of the mass of colored middlings. By this intermediate purifying operation, such colored middlings were cleansed of the speck-producing matter and rendered "white": so that when they were reground, the flour produced was white instead of colored, and was practically free from contamination by specks of fine bran. Cochrane was thus able to obtain a larger proportion of white flour from wheat than was previously practicable with the American system of low milling; and, from a peculiarity in the structure of wheat, this flour so obtained was of a higher quality—the peculiarity referred to being that the best flour-yielding portions of wheat are the hardest and least easily ground, and consequently the flour-yielding portions of colored middlings, which from their hardness have escaped the first fine grinding, yield when cleansed of bran-specks a flour of a higher quality than that of the softer portions of the grain, which yield to the first grinding, and form the superfine flour obtained at the first bolting. So long as the flour obtained from these harder portions was a mixture of good flour with bran-specks, as it was under the previous American system of low milling, the middlings-flour, as a whole, was inferior in quality to superfine flour; but when the contamination is prevented, the flour produced from the white middlings becomes of the full value due to the high quality of the portions of the wheat which produce it.

A good description of the two processes, the one now commonly known as the American system or low grinding, and the other as *mouture économique*, may be found in the *Manuel Roret* for bakers, grain merchants, millers, and builders of mills, published at Paris, 1856, commencing at vol. II., page 355. In the former process the grain is ground to chop or meal, which is treated by bolts in the well-known American fashion; and in the other process, *mouture économique*, there is a first grinding of the grain by the use of stones, then a separation of the offal by sifting, then a second grinding and a second separation by sifting, and so on in succession through five grindings.

The following are the successive steps which the grain passes through in the new process: 1. The grinding of the grain to meal, as opposed to mere cracking of the grain; 2. The bolting of this meal or chop to remove and secure the superfine flour; 3. The purification of the remaining or resulting middlings by screening and blowing, thus removing from the middlings pulverulent impurities; 4. The regrinding of these middlings so freed from pulverulent matter; 5. The rebolting of this reground product, so as to produce flour from the reground purified middlings. The third step of the process is the one in which the purifier is used, and according to the Cochrane invention such a machine for separating the impurities from the middlings consists of a hexagonal screen inclosed in a tight box or trunk; a trapped feed or feeding contrivance, which will feed in the material to be operated upon, and prevent the passage of air; a fan, which causes a current of air to act upon the material inclosed in the reel or screen; and a collecting chamber so constructed that the current may pass through it, and so that it will cause some or all of the pulverulent impurities floating on the current to be deposited. It will be seen that the new process involves both a process and a machine for carrying out the most important step in the series of operations. In the purifier the middlings are subjected to screening and blowing for purification at the same time; or in other words, both screening and blowing are taking place at the same instant, and the middlings may be so screened and blown while in a state of mixture with the bran, shipstuff, shorts, etc.; but this screening and blowing takes place prior to the regrinding of the middlings, and after the separation of the superfine flour. The third step, in which the purifiers are used, is the important one, and the carrying off of the pulverulent impurities by the air-current acting upon the middlings containing these light impurities is the essence or gist of this part or step of the process; and provided such impurities are so carried off, it matters not whether the screen be hexagonal or flat, or whether the middlings are confined within it or can pass through it, so long as the middlings are so held that a blast or current will act upon them to carry off these pulverulent impurities.

In the American system as practised before the introduction of the new process, it was the object

of every miller to pass as much grain as possible between the stones—that is, as much as could be so passed without undue heating—and to produce as much flour as could be produced by such passage, the further object incidentally being to reduce the production of middlings, which at that time and according to that process was about 8 per cent. of the total production. The effect of the new process is to produce as much middlings as possible, and as is consistent with the production of good superfine flour. The proportion of middlings obtained by the new process is about 50 per cent. of the total product. The first grinding is no longer the rapid operation which it was, but, because of the greater distance apart of the stones in the new process, the number of bushels of wheat passed between each run of stone per hour has fallen immensely. The new process requires that the first grinding operation shall be carried out between stones set close enough to produce what is called the superfine flour, and not set as in the European system of high milling, where the grain is merely cracked. At the same time the stones must not be set as in the old American system of low milling, where the effect was to produce the greatest yield of flour. It may be said that the new process system in the setting of the stones is practically somewhere between the two extremes, the high milling as practised abroad and the low milling as practised in this country.

By referring to the article Middlings-Purifiers the reader will understand the machine which is necessary to the carrying out of the new process. This process we illustrate by the diagram Fig. 3003, which shows the various steps both before and after the middlings have passed through the purifier. It must be remembered that the process here illustrated may be materially altered in many important respects; but whatever variations may be made in it, the essential feature of the purifier in some shape must be included. At *A* will be seen the millstones which grind the wheat into meal, and from which the ground product comes in a warm and rather closely-ground condition. The ground meal is next elevated to an upper story of the building by a mechanical elevator called in the diagram "wheat-meal elevator," and from which it is discharged into a "hopper-boy." While in the "hopper-boy" the meal is cooled, and it is delivered from it to a reel or series of reels, one of which is shown at *B*, in which the meal is bolted. The reels are "clothed" with bolting-cloths, the meshes of which are fine enough to extract the superfine or "Extra State" flour, the cloth in each reel being of increasing fineness; that at the head of each reel is known as No. 10, and farther on as No. 11. The flour thus extracted is delivered as shown by the arrows down to the packing-chest marked *H*. The materials which pass out at the end of the reel or the series of reels *B* are conducted as shown by the arrows to a reel or series of reels *C*, which separate the mass into middlings, shipstuff, and bran. The shipstuff and bran are then conducted to the proper receptacles (not shown), and either the bran alone or both the bran and shipstuff are passed through a bran-duster before entering the receptacle in which they are to be deposited. The middlings coming from the reel or series of reels *C* are then conducted as shown by the arrows into a reel or series of reels *D*, in which the fine matter that may have been mixed with the middlings is dusted from them, and is either sent to the packing-chest *H*, or returned to the head of the series of reels marked *B*, according to the quality of the flour which it is wished to produce. The middlings are delivered from the end of the reel or series of reels marked *D*, and are conveyed directly to a middlings-purifier, one or more purifiers being used. One of the purifiers is shown in section in the diagram at *E*. The middlings delivered to the purifiers are subjected to the action of the shaking screens, and of the currents of air passing through the purifiers by the operation of exhausting fans, the practical effect of which is to remove from the middlings the pulverulent impurities and such other light matter as can be carried off by the currents of air. Some of the pulverulent impurities and other light matter separated from the middlings are collected by gravitation in pockets formed in the upper parts of the purifiers. The residue is conducted by the eduction pipes of the fans to a dust or settling room shown in the diagram, in which the particles are permitted to settle by gravitation, while the air is permitted to pass off. The purified middlings coming from the purifiers are conducted to millstones shown at *F*, and are there reground. Thence the meal is carried up in the elevator as shown, and rebolted by a reel or series of reels marked *G*; and the flour obtained from the middlings is conducted as shown into the packing chest *H*, where it is mixed with the superfine or "Extra State" flour obtained from the reels *B*, the mixture making one straight grade of flour ready for the market.

As has been said before, this process may be materially altered in many respects, but the diagram gives a clear understanding of the leading stages through which the materials are passed in making "New Process" flour according to a successful and well-tried plan.

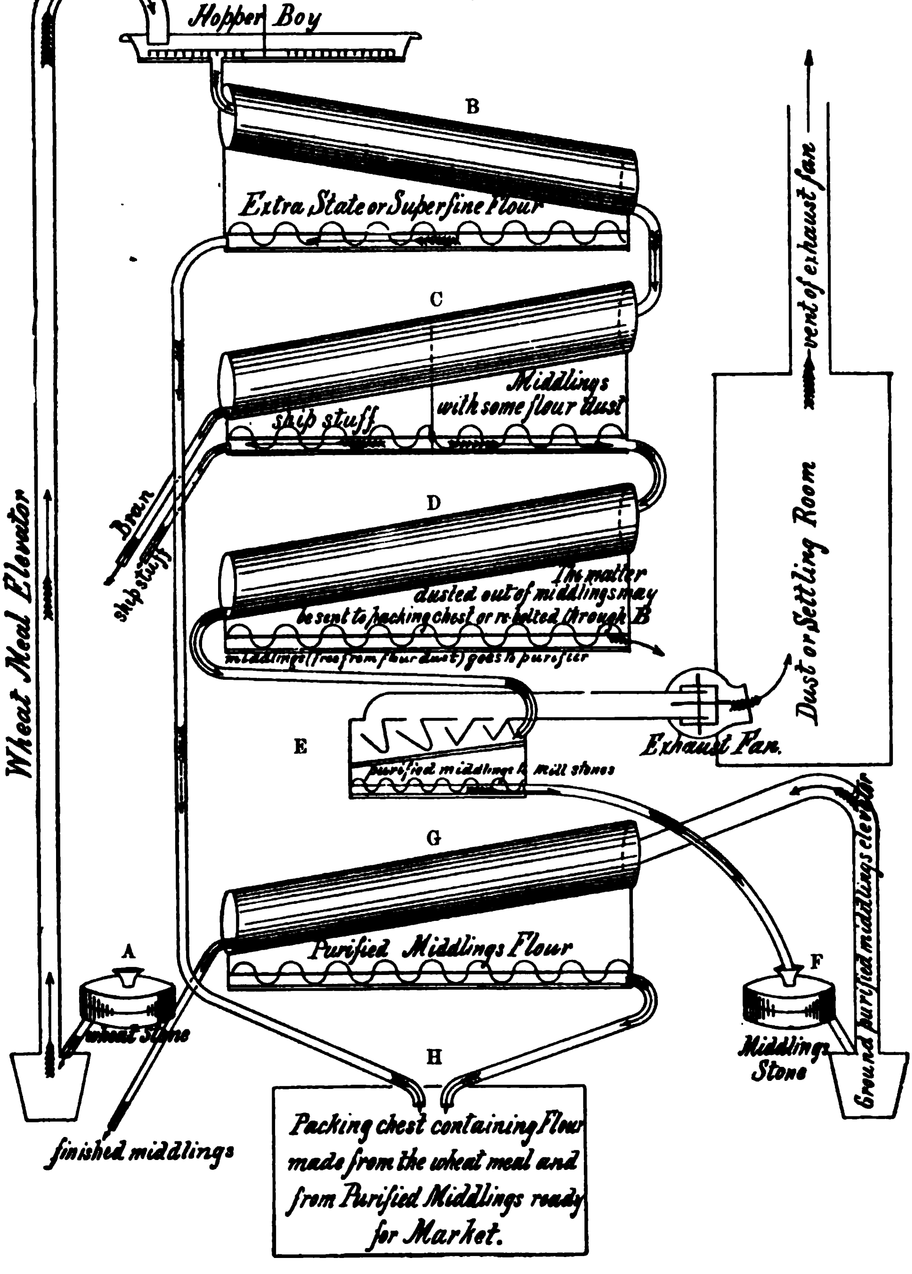
At the present time* reels are made as long as 20 ft., but the tendency is to decrease the length as much as possible. The usual diameter is 32 in. "The speed of reels should be from 28 to 32 revolutions per minute for reels of this size, larger reels having a less speed, of course, and smaller reels a greater. The proper pitch for reels may be stated as a fourth of an inch to the foot of length. Bolting-chests may be driven either by gearing or belting, preferably the latter. When spur-gearing is used, an additional frame must be provided at the head of the chest, and should be distant from the main frame about 2 ft. This frame can be made of posts about 10 by 4 and bridge-trees of similar dimensions, and its purpose is to carry the short shafts by which connection is made with the reel-shafts. When bevel-gear is used, this additional frame is not necessary, as the cross bridge-trees can be extended to form bearings for the upright shafts that drive the conveyers and reels. The frame of the bolting-chest should be substantially made, and the different posts and bridge-trees securely keyed together. Almost any kind of wood can be employed for the covering of the chest, pine generally being used. For the cant-boards some lumber should be used that is hard, like walnut, and is susceptible of wearing its surface smooth. These gathering boards must have the proper pitch in order to prevent the flour from adhering, and so proving a source of annoyance. An angle of from 65° to 70° is suitable for this purpose. The side rails and posts of the

* *American Miller*, vols. vi., vii.

bolting-chest need not be so heavy as the other timbers, 2¼ by 6 being heavy enough for the side rails, and 3 by 8 for the side posts. The corner posts should be 13 by 3 in., and the bridge-trees the same size as the side posts.

"All bolting is accomplished on the sliding principle, and therefore the ribs should not be made heavy, but should be flat or leveled off from the upper corner on the carrying side. By this means

3003.



the meal is allowed to slide gently on the cloth, which not only increases the capacity of the reel, but does better work than a dumping-reel will do. The philosophy of the sliding principle is, that the bran and light impurities, having less specific gravity than the flour, float on the top, leaving the flour next to the cloth, and presenting no impediment to its passage through the meshes. The best

way to make up bolting-cloth is to cut it into strips and have ticking put on every rib. If the reel is 30 in. in diameter, the cloth, being 40 in. wide, will cut into three strips, each 13¼ in. wide. Allowing half an inch both sides, each of the three strips will be 12¼ in. wide. The distance from the centre of one rib to the centre of the next rib being 15 in., 2¾ in. of ticking must be added on each rib to make the required 15 in. Cloths made up with ticking last longer than those made up without it, for the reason that bugs will not attack the ticking, and whatever strain is brought to bear within the reel falls upon it instead of the cloth. In making up the cloth, care should be exercised not to stretch it, since it will be wrinkled and will not fit properly when placed upon the reel. Ordinarily, bolting-chests contain four reels, and when more are required they are ordinarily arranged by twos. The reels should all be pitched one way, and the heads should be placed in one direction. The chest should be partitioned in the middle and two conveyers placed under each reel. When a speck-box is used, care should be taken to have it perfectly tight around the heads of the reels, so that the specks cannot work back."

The following is an ideal bolting arrangement suitable for a merchant mill of 14 run of burrs, 8 on wheat, 3 on middlings, 2 on bran, and 1 on tailings, with appropriate purifying capacity and rolls for crushing wheat. It is not given as a model, but simply to illustrate the principles of bolting. It is taken from a paper prepared by Mr. Gent of Columbus, Ind., and read before the State Association of Indiana at its meeting in May, 1878. The chests are designated as follows, and whether the reels are in one chest or more, they should be so arranged with spouts and elevators that any part of the product from any reel can be thrown into the head of any other reel or chest of reels:

"Chest *A*, one reel, for scalping the chop, which should be closed with two grades of wire, the finest at the head, with slides so arranged that all or any part of the bran could be taken off; for at times the chop will not bolt so freely as at others, and will require more of the fine bran to make it bolt well. Chest *B*, four reels, for bolting the chop. Chest *C*, four reels, for bolting the middlings after being ground. Chest *D*, four reels, for rebolting the flour from all sources when required. Chest *E*, four reels, for separating and dusting the middlings from chest *B*, or chop-reels. Chest *F*, two reels, for bolting, dusting, and separating the products from the rolls. Chest *G*, two reels, for dusting and separating the second middlings from chest *C*. Chest *H*, two reels, for dusting and bolting the bran after being ground. Chest *I*, two reels, for dusting the fine bran, dust from dust-room, and tailings from chest *F*. Chest *J*, two reels, for grading middlings before going to purifier. The chop passes to reel *A*, or scalping reel, where as much of the bran as possible should be disposed of, and, if brushed before grinding, passed to the brush and to the stone, and to chest *H*, for bolting and dusting. The chop now passes to chest *B*, where the process of bolting begins. After passing through chest *B*, the middlings and fine bran pass into chest *E* for separating and dusting, the fine bran passing over the tail and to a stone for grinding, the germs and heavy portion passing through a coarse cloth on the tail of the separating reel, and to the reels for crushing. The middlings are transferred to grading-chest *J*, clothed with six grades of cloth, and, when graded or sized, each grade is put on a separate purifier, and after purifying are divided into two grades, and to separate stones for grinding, while that portion which passes over grading-reels goes to the roll with those particles which were taken off at the tail of reel *E*. This completes the work of this roll, and we will call this roll number three. The middlings, after grading, are transferred to chest *C*, with as much of the flour from chest *B* as is considered good enough for that purpose. The flour from this chest is the first or best grade. The return from this chest, also the return from chest *B*, and the flour from the dusting-reel, with the flour from the head of chest *H*, or bran-reel, and the dusting from chest *G*, or second-middlings reel, and the flour from chest *F*, or from rolls, are all thrown into chest *D* and rebolted. The flour from this chest is the second grade; while that which passes over the tail of chest *D* is turned on two purifiers, cleaned of the fuzz, and sent to a stone for light grinding, and then into the chop again. The second middlings from chest *G*, after passing over two purifiers, are sent to the same stone and into the chop. The return from chest *D*, or rebolting reels, is thrown upon the head of the bran-reels in chest *H*. The heavy particles of middlings from the first dust-chamber pass to reel number four, and from there to chest *F*, with product from reel number three. The tailings from the first six purifiers go to roll number five, then into chest *F*, with that from rolls number three and four. The middlings from chest *F* go on a purifier for that purpose, and to the stone for light grinding, and into the chop, while that which passes over the tail of the reel goes to a stone for grinding and to chest *I*, together with the chop from the stone grinding fine bran. The return from the first bran-reels, or chest *H*, is thrown into this reel. This is the third grade of flour, and if well managed will only amount to 6 or 8 per cent. of the whole; the second 42 to 44 per cent., and the first 45 to 50 per cent."

Cleaning Bolting-Cloths.—Various devices have been proposed for the purpose of keeping bolting-cloths free from paste, etc. One of the best inventions is that of Messrs. Rathbun Brothers, of East Pembroke, N. Y. The contrivance consists of spring-bolts securely fastened to the insides of the cross-stripes on the tail end of the reel, to the inner end of which are attached strong cords of gut running directly under the cloth and fastened at the head. On the bridge-tree at the tail of the reel is secured a circle, to which is attached a steel-faced cam in such a way that it will turn back if the reel is turned backward, but if held in position it causes the spring-bolts to crowd in as the reel revolves. This slackens the cords, and as the spring-bolt passes the cam the reaction of the spring causes the cord to snap against the inside of the cloth, thereby removing the flour and the impurities which have caught on the cloth, and causing them to fall back into the reel.

The Cogswell & Finn bolt-cleaner consists of a brush suspended over the reel by arms secured to a shaft. The reel is cleaned through its rotating in contact with the brush. H. L. B.

MILLING MACHINE. The milling machine has assumed a position of great importance in the manipulation of iron work, especially that of small dimensions. The advantages it possesses are as follows: 1. Having a rotary cutter, the cutting operation is, so far as the cutter is concerned, continu-

ous. 2. The outline of the work assumes a form in exact truth with the outline of the cutting edges of the cutter. 3. The machine being once adjusted, all the work operated upon therein will possess exact uniformity in size and form. 4. By varying the position of the work beneath the revolving cutter or cutters, pieces of work of uniformly irregular shape may be duplicated with an assurance of exactitude in both size and shape. 5. The only special skill required to operate the machine consists in maintaining the form of the cutters and in setting the work. For these reasons the milling machine is applied to every form of small work which will admit of manipulation by rotating cutters, more especially in the manufacture of sewing machines and rifles. Even screw-cutting taps may be threaded by milling tools.

The milling machine consists essentially of a framework carrying a spindle revolved by a cone-pulley, either alone or in combination with gear-wheels whereby to obtain more changes of speed and greater driving power to the cutter, the same frame carrying a table whereon chucks or work-holding devices of various forms and sizes may be fastened. The chuck or work-holding device is then traversed beneath the rotating cutter, or is sometimes made to revolve, or to revolve and traverse at the same time, as in the case of milling out the flutes of twist-drills. In rare cases the work is stationary and the milling cutter is traversed.

The Universal Milling Machine, made by the Brown & Sharpe Manufacturing Company, shown in Fig. 3004, and also in a full-page engraving, has proved one of the most successful yet devised for general purposes. The spindle $C\,C'$, for carrying the cutters, has its journal-bearings in the frame A, which is made hollow, a shape giving great rigidity, and forming a closet for the tools and appurtenances to the machine. The arbor for holding the cutters is separate, and fits into a conical hole provided in the spindle at C'. Over the spindle $C\,C'$ is an arm H extending across over the spindle-cone, from the front to the rear bearing, and projecting toward the front of the machine, to which is clamped the piece J, carrying the centre B, for supporting the outer end of the arbor, the centre being moved for adjustment by the hand-wheel I. The piece J, holding the centre B, is split on its upper and lower ends, and closed by clamp-screws upon H to hold it in position, and also upon B to hold it firmly. E is a table or clamp-bed, which can be moved upon the knee D in a line parallel to the axial line of spindle, and clamped firmly in any position. Upon the bed E is another, F, which has a movement in a horizontal plane, at right angles, or any angle between 45° and 90°, to the axis of spindle $C\,C'$, either to the right or left. Upon the bed F is placed the spiral head G and centre stand G'. Between the centres G and G' is placed the work to be operated upon, if of such form as to be best held upon centres, as spiral drills, reamers, taps, milling-cutters, or work of a similar character; and the work is adjusted to the cutters by the raising of the knee D by the vertical screw D', the amount to be raised or lowered being regulated by nuts upon the vertical stop-screw F' acting as stops upon each side of an ear through which it passes. It can also be raised by thousandths of an inch, indicated by a pointer upon a dial fastened to the front of the knee D. A vise for holding flat pieces for milling is provided, which can be fastened upon the bed F, at any angle with the same. The spiral head G can be elevated at any angle for the purpose of cutting any work, upon an arbor fitted to the same, or held in a universal chuck, fitted upon the spiral spindle A.

3004.

The arrangement of the cone-spindle bearings and back gear is shown in Fig. 3005, which is drawn partly in elevation and partly in section. $A\,A$ is the frame, having the conical bearings $T\,T$ for the spindle $C\,C'$. The front bearing is made solid, and forced into a hole bored in the frame to receive it; the wear is taken up by nuts which draw the spindle into the conical bearing. The rear bearing is conical upon the outside, fitted to a hole in the frame, into which it is drawn by a nut, the wear being compensated for by the box being split upon one side, the drawing of the box forward closing it upon the spindle. U is the conical recess to receive the arbor. M is the cone-pulley to drive $C\,C'$, and L and L' the gear-wheels for the slow motion. $Q\,Q'$ is the back-gear sleeve carrying the gear-wheels $S\,S'$; this sleeve revolves upon a shaft Q, which has its bearings eccentric to the part upon which the sleeve fits, and has upon its outside end a lever O, R being a device for retaining it in position. The shaft Q is hollow, and filled with oil by removing the screw shown in lever O, for the purpose of lubricating the bearing for sleeve Q'. As shown in the drawing, the gear-wheels L' and S, also L and S', gear together; hence motion to $C\,C'$ is obtained as follows: The pulley M is revolved by belt, and L' being fixed to M revolves with it, rotating the gear S; this rotates the sleeve Q' upon the shaft Q, and the gear S', being in one piece with the sleeve, rotates L, which, being fast upon $C\,C'$, gives rotatory motion to the latter. When, as for light work, motion is required from the cone-pulley direct to $C\,C'$, the locking device shown at N is moved, locking L to $C\,C'$; the handle O is depressed, rotating the eccentric shaft Q through one half revolution, which carries S

THE UNIVERSAL MILLING-MACHINE.

out of gear with L', and S' out of L. P is a cone-pulley having three steps to regulate the feed of the machine.

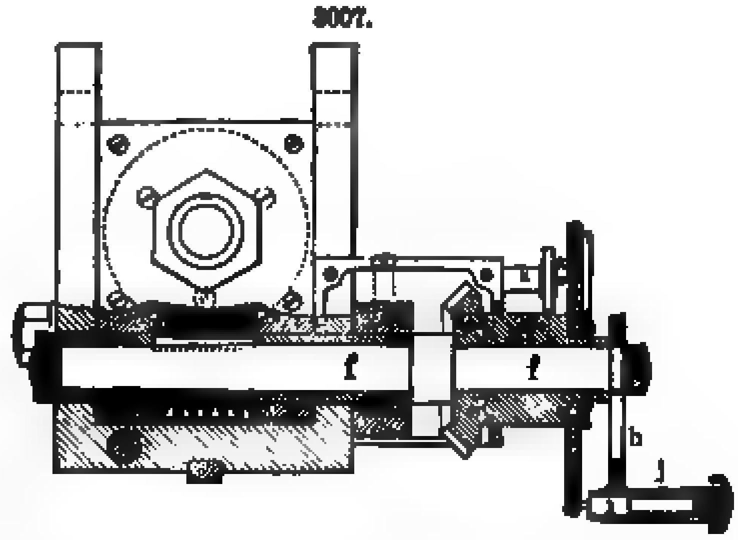
In Figs. 3006 and 3007 is shown the construction of the device shown in Fig. 3004 at GG', which is employed for some kinds of work. It consists of two heads, one of which carries a spindle, which may be rotated continuously or moved with precision through any required portion of a revolution. Into this spindle, a, Fig. 3006, fits the centre b, which holds the work (or an arbor upon which work may be held) at one end, while a similar centre in G', Fig. 3004, holds it at the other end, after the same manner as work is held in lathe-centres. c is a clamping device, whereby the dog or driver upon the work or mandrel may be held in a fixed position with regard to the spindle a. Upon the spindle a is fastened a worm-wheel d, engaging with a worm e, which is fixed to the shaft f, standing axially at a right angle to spindle a. Upon f is a dial or index-plate g, whose outer radial face is drilled with rows of holes, of different numbers, but the holes in each row being equidistant.

3005.

In Fig. 3007, h is an arm carrying an index-pin i, which arm may be fastened upon f in such positions as to bring the pin i opposite either of the rows of holes upon plate g. A spiral spring at j forces the point i into such of the holes in g as it may be opposite to. Upon the back side of plate g is a pin k, sliding in a part of the head, which is opposite one of the rows of holes in plate g, and drilled through the same; this pin, being pulled forward into one of the holes, fastens the plate to

3006.

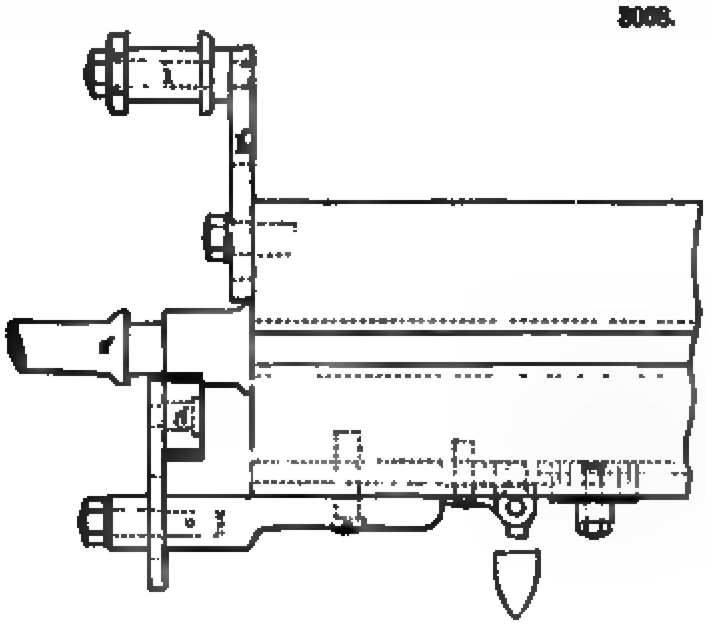
3007.



prevent its revolving while using the arm h. Upon the face of the plate g, and held to it by friction, is a sector formed of two arms, which may be opened to any angle, and embrace any number of holes in the plate; and having been set at the requisite number of holes, the pin i may be moved between the arms without counting the holes at each movement. If the pin i is adjusted to one of the concentric rows of holes, and placed alternately in each hole, the spindle a will have been rotated, but its motion will have been divided into as many periods as the number of teeth in the worm-wheel, multiplied by the number of holes in the row of holes being used. As an example of the operation of this part of the device, let it be supposed that there is placed therein an arbor containing one or more hexagonal nuts. The point i is adjusted to the requisite row of holes, the pin i is withdrawn from the index-plate, and the latter is rotated until one of the sides of the nuts stands parallel with the face of the milling-cutter, when the pin is allowed to enter one of the index-holes. The slide F, Fig. 3004, is then traversed, passing the nuts (forming the work) under the milling-cutter, and back again

to the position whence they started; the pin i is then withdrawn, and the shaft and worm rotated the number of turns and parts of turns required to make one-sixth of a revolution of spindle a, when the pin i is allowed to enter the hole opposite it. The work is then again traversed beneath the milling-cutters, and the above operations are repeated. Thus by setting the pin i to the proper circle of holes in g, and making the requisite number of turns and parts of turns, the spindle a may be moved through any portion of a revolution with great precision, and the work may have any number of flat sides, teeth, or grooves cut upon it. In case the grooves upon the piece are wanted in a spiral form, the spindle a must have a continuous rotary motion, at the same time that it is being revolved in a longitudinal direction, which is effected by means of connecting gearing between the feed-screw moving the bed F, Fig. 3004, and the shaft f, Fig. 3007; and by suitable change-gear the spiral may

3008.



be made longer or shorter, as may be required, and either right- or left-handed. The spindle a and head n may be set at any angle between a horizontal and a vertical plane, the centre of motion being the shaft f, and the top edge of box or frame m being divided into degrees for that purpose. It is clamped in any position by a bolt passing through both head and box, and a nut upon the outside.

The self-acting feed-motion for the bed F is produced by a belt from the cone-pulley P, Fig. 3005, to similar cones upon the side of the machine, driving by means of an extension coupling and universal or Hooke's joints the shaft b'', Fig. 3008. To this is fitted a clutch f'', with a feather allowing a movement longitudinally upon it by means of a fork connected by a bell-crank lever to a slide contained in a groove in the side of the bed, and operated by a lever or a movable stop attached to the slide, which comes in contact with a pin disengaging the clutch f'' from its mate e'', to which is

3009. 3010.

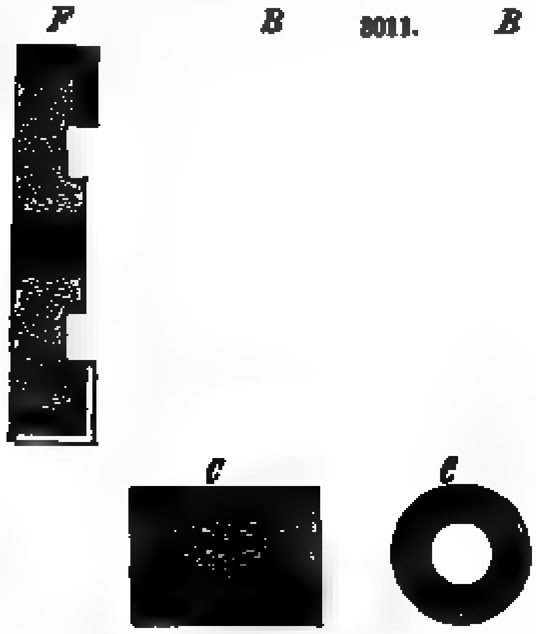
fastened a bevel-pinion engaging with the crown-gear D'', which is fast on the feed-screw s''. If the bed (of which s'' is the feed-screw) requires to be operated by hand, e'' and f'' are disengaged (as shown in the drawing), and the handle at the other end of the feed-screw is employed. The adjustable arm h'', with its stud and sleeve, is for carrying the gears for actuating the dividing or index device shown at G, Fig. 3004. The arm and gear n' is used for an intermediate when cutting left-hand spirals.

Milling-Cutters.—The improvement in these cutters devised by the makers of the machine described consists in making the teeth of the cutters of exactly the same section or shape from the front to the back, giving the cutting edge clearance by making the back of the teeth to approach the centre of the cutter, decreasing the width of the spaces between the teeth in order to maintain the teeth of regular form from edge to root, as shown in Fig. 3009. To sharpen these cutters, the front faces of

the teeth are operated upon by an emery-wheel, thus saving the softening process and maintaining the original form. This is of the utmost importance in this class of tools, remedying one of the former greatest objections to milling tools.

The ordinary description of cutting tool used in the milling machine is shown in Figs. 3010 and 3011. It may be employed to cut either upon its circumferential surface, as shown at H, or upon its radial

3011.



3012.

3013.

face, as shown at $B\ B$. A is the arbor driven by the milling-machine spindles; $B\ B$ are two cutters; C is a washer, maintaining $B\ B$ the required distance apart; and D is the work being operated upon. An advantage in using where practicable the radial faces of the cutters is, that they will cut the work true even though the cutters themselves are out of true, the pieces of work all being cut to one size, because the more prominent teeth of the cutters will operate upon all parts of the work; the only

3014.

3015.

result of a want of truth in the cutters being that the work will be cut narrower with the same length of washer than it would be were the cutters true.

When the side faces of the cutters operate, they must be made right and left; that is to say, the teeth of one cutter must slope in the opposite direction to those on the other cutter, so that when the two are placed opposite to one another, as shown in Fig. 3011, the teeth of both will stand in a direction to accommodate the direction in which the cutters revolve. To cut side faces of any required width, we have only to vary the width apart of the cutters by the washer C in Fig. 3011,

while to cut curves and shoulders the periphery only of the cutters can be used. Thus, suppose it were required to cut out the form shown in Fig. 3012, the outline of the cutter would require to be as shown in Fig. 3013; but it would be a tedious and difficult matter to get up a solid cutter of such a shape on account of the difficulty of cutting the teeth. Hence, all such compound forms are produced by making separate cutters, each of its requisite form, size, and width, and then placing them

3017.

together to make up the whole. Thus the figures from 1 to 8 represent each a separate cutter. It is obvious then that there is scarcely a limit to the forms capable of being smoothly cut and uniformly duplicated by such cutters.

French Milling or Fraising Machines.—A series of milling machines adapted to various purposes have been devised by M. Frey fils of Paris, and are remarkable for exceedingly ingenious construction and high capabilities.

Figs. 3014 to 3017 represent a machine specially devised for producing milling-cutters of determinate form. It has a universal motion which allows of the outline of a pattern being accurately followed. Fig. 3014 is a vertical section across, and Fig. 3015 a vertical section along the axis of the carriage. Figs. 3016 and 3017 are plan views. The principal support is a hollow cast-iron column A. This is surmounted by a cap A', which has two branches, one of which supports the shaft of the driving-pulleys and the other the drum by which motion is transmitted to the working tool. The upper part of the column has a support B for the carriage C, on which moves perpendicularly the carriage D. On the front face of the latter are made two channels a, to receive the bolts b, by means of which the support E of the tool-carrier is fixed. The bolts also serve to secure the guide-

3043

3042.

carrier *F*. The second carriage *D* has a universal movement, since it slides vertically on the first carriage *C*, while the latter has a horizontal motion on its fixed support *B*. In the centre of support *B* is a ball *c*, held in a socket *d*. A second sphere *c'* is mounted in the middle of the exterior carriage *D*. These two balls are traversed by the rod *G*, which by a chain *e* is connected with the pivoted lever G^1, on the end of which is a counterweight G^2. It will be evident that by means of the rod *G* the workman is enabled to move the tool-carriage in any direction about the centre of the ball *c*, and thus to guide the tool as may be desired.

In front of a rectangular opening in the column *A* is adjusted the table *H*, on the surface of which is placed the carriage *I*. Above the latter is the principal carriage *J*. This is connected with a plate *K*, which, as shown in Fig. 3015, is so arranged that the upper carriage may move on a horizontal fixed centre in the lower carriage. It will be observed consequently that the upper carriage *J* has a variety of movements. It may be adjusted vertically, displaced longitudinally, or placed at any degree of obliquity. The centres for holding the work *X* are shown at *L* and *L'*. Also on the carriage *J* are the pattern *M* and the carrier *M'*, which bear the same relation to the guide *X'* as does the tool *X* to the work to be milled.

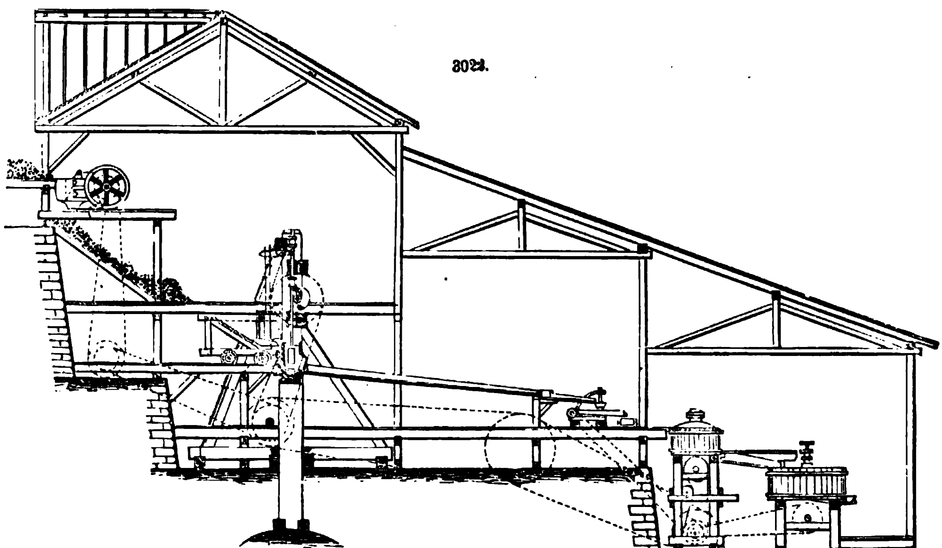
Horizontal Milling Machine.—A sectional elevation of this machine is given in Fig. 3018. It consists of a hollow cast-iron rectangular support *A*, which receives above the spindle *B* and on its front face the table *C*. On the front of the base of the column is cast a piece *A'*, which receives the bronze nut *a*, the threaded stem in which serves to effect the vertical displacement of the table. Journals *a'* also, of cast iron, receive the motive-arbor *D*, at the extremities of which are the fixed and loose pulleys *P* and *P'*. Also in this shaft is the stepped cone D^1, which transmits motion by a belt to the cone D^2 on the sleeve B^1 of the spindle. Motion may be imparted to the main spindle either directly by the means described, or by the back gearing. The carriage consists of a lower portion *F*, which moves parallel to the axis of the support *C*; and above this is a second portion *G*, with channeled surface, which has a movement perpendicular to that of the part below. The entire table may also be bodily moved toward or from the tool. The tool used is represented in Fig. 3019. Its form is that of a crescent with two cutting points spirally disposed. Its stem is inserted in the spindle-head, and held from turning by a squared end entering a similarly shaped socket. In place of this tool a twist-drill may be substituted for boring, or other suitable implements may be introduced for surfacing, grooving, etc. The manufacturer states that pieces of work 15.6 in. high, 15.6 in. in breadth, and 58 in. in length may be operated upon with facility in this machine.

Fig. 3020 is a vertical section and elevation of a machine designed for all the varieties of work of which an apparatus of this class is capable. It mills, dresses, surfaces, and drills both vertically and horizontally. Fig. 3021 shows a front view of the same machine, with the drill arranged for horizontal boring. The details of construction are clear from the engravings.

MILLS, GOLD, SILVER. AND COPPER. See AMALGAMATING MACHINERY, BREAKERS OR CRUSHERS, CHLORINATING MACHINERY, CONCENTRATING MACHINERY, FURNACES (METALLURGICAL), and STAMPS, ORE.

GOLD-MILLS.—The general arrangement for a mill for the treatment of gold quartz is shown in Fig. 3022. Where it is possible, a side-hill location is selected as the site of the mill, the object

3022.



being to secure through the action of gravity a continuous automatic movement through all the different stages of the process. If, as is most desirable, the mill adjoins the hoisting works, or is connected thereto by a narrow-gauge track, the ore is brought thither from the various levels of the mine in the same cars that are loaded at the stopes or headings. These cars discharge upon an in-

clined wrought-iron grating termed a *grizzly*, which allows the fine particles to drop through into the bin, while the larger ones are carried on to the rock-breaker, where they are rapidly reduced, between heavy jaws of chilled cast iron, to fragments of any size required. These fall to the bin below, and pass on with the screenings to the self-feeder. This latter is set in a strong frame that rests on wheels as shown. It is located behind the battery of stamps, and is operated automatically through the tappet upon the central stamp-stem of the battery. The supply to the mortars is thus regulated at will. As gold ores are almost universally treated according to the wet process, and the amalgamation is conducted in the mortar of the battery, the die is made to set low as shown, and the sides and screens are lined at the bottom with silver-plated copper plates, to collect the amalgam as rapidly as it is formed. Whatever fine particles of the precious metal succeed in escaping from the copper plates in the mortars, and passing the screens, are brought in contact with other plates upon the aprons, or are caught upon the inclined blanket-tables just beyond. Here a mechanical separation of the lighter earthy materials of the pulp, from the heavier grains of gold or gold-bearing sulphurets (if these are found in the ore), is continually taking place. Where the ores are free-milling and wanting in sulphurets, the fine gold which is still uncollected, and is being carried away suspended in the muddy water, is led over a succession of tailing-sluices, where the greater part is caught. The gold-mill shown is arranged for the treatment of sulphurets that are refractory, and require a special process. These sulphurets, or "black sands," as they are termed by the practical millman, are separated from various earthy matters by means of the concentrator shown. These are then ground to a pulp, sometimes with the addition of the tailing in an ordinary pan. When the quicksilver introduced has had time to reach each scale of gold, and thorough amalgamation has been effected, the contents of the pans are led off to the settler, where the earthy matters are kept in motion until they are discharged with the water, while the amalgam is removed to the retort-room, where the final separation is brought about, the quicksilver being sublimed and collected under water to be used again, while the gold is in a condition to be assayed, remelted, and cast into ingots, in which shape it passes as an article of commerce.

Gold-Mill Performances.—The following data, by Messrs. Prescott, Scott & Co., show performances of gold-mills:

Keystone Consolidated Mill, at Amador Co., Cal.—Gold-mill, crushing wet.—Number of mortars, 8; discharge of mortars, single; number of stamps to each mortar, 5; total number of stamps, 40; weight of a stamp in pounds, 750; height of drop in inches, 8¼; number of drops per minute, 85; screens made of Russia iron, slotted; trade number of the screens, 5; tons of rock crushed per 24 hours, 90; tons crushed per stamp per 24 hours, 2.25; quality of rock, medium; formation, quartz; fineness of the bullion, 840.

Hunter's Valley Mill, at Mariposa Co., Cal.—Gold-mill, crushing wet.—Number of mortars, 6; discharge of mortars, single; total number of stamps, 28 (4 mortars with 4 stamps each, and 2 mortars with 6 stamps each); weight of a stamp in pounds, 650; height of drop in inches, 11; number of drops per minute, 70; screens made of Russia iron, punched; trade number of the screens, 6; tons of rock crushed per 24 hours, 50; tons crushed per stamp per 24 hours in 4-stamp mortars, 1.75, in 6-stamp mortars, 1.83; quality of rock, easy; formation, quartz.

SILVER-MILLS.—Mills for the treatment of silver quartz differ in the details of construction with the character of the ore. Although there is a very wide range between the free-milling ores and those that are too basic to be successfully worked by these means, yet all quartz-mills for the reduction of silver ores can be referred to one of two general types, according to whether water is used or not in the process. They are known respectively as "wet-crushing silver-mills" and "dry-crushing silver-mills."

In the "dry-crushing silver-mill," as shown in Fig. 3023, the ore that is not fine enough to pass the grizzly is crushed to the size required by a rock-breaker, and the whole spread upon a drying floor as shown, where it is heated by the waste gases from the furnace until every particle of moisture has been evaporated. It is then shoveled into the hopper of the self-feeder, from which point until it is discharged from the furnace it is handled and moved entirely by mechanical devices. The pulp, after it has passed the screens, is delivered into a conveyer on each side of the double discharging mortar, which carries it to the elevator-bin. From here it is raised by the belt-elevator shown, operated from a countershaft, and discharged into the pulp-feeder as rapidly as required. By means of a set of cone-pulleys the speed of the pulp-feeder shaft is varied at pleasure. The pulp, carefully mixed with salt, is sifted into the vertical shaft of a Stetefeldt furnace. The desulphurization and chlorination occur almost simultaneously during the descent of the finely-divided particles; the roasted pulp is drawn from the furnace, by the door at the bottom of the shaft, on to the cooling floor, and is then charged into the amalgamating pans. These pans make from 80 to 100 revolutions per minute, and take from 3,000 to 4,000 lbs. of ore or pulp at a charge. After the grinding and amalgamating have been effected, the whole charge is run into a settler, which makes about 12 or 13 revolutions a minute. This movement and the flow of water are sufficient to carry off all the lighter particles of earthy matter, and allow the amalgam to drain into the amalgam safe. This latter is emptied from time to time, and the contents are retorted, the quicksilver used over again, and the bullion remelted, assayed, cast into ingots, and its assay value marked upon it for commercial purposes. A clean-up pan is sometimes placed at the bottom of the mill for washing the bullion, or there may be added a sulphuret-pan to treat the sulphurets and tailings collected.

In the "wet-crushing silver-mill" the process of separating the precious metal from its matrix of vein-matter is known almost universally as the "Washoe" process. The ore, after it has passed the rock-breaker, self-feeder, and battery, and been reduced to the proper condition of fineness, is run into settling-tanks, where the water is allowed to drain off. The various steps in the process that follows are essentially the same as those in the dry-crushing silver-mills. (See also AMALGAMATING MACHINERY.)

Silver-Mill Performances.—The following data exhibit the performance of the International Mill at White Pine, which has 60 stamps, 30 crushing dry and 30 crushing wet:

Silver-mill crushing dry.—Number of mortars, 6; discharge of mortars, double; number of stamps to each mortar, 5; total number of stamps, 30; weight of a stamp in pounds, 750; height

3028.

of drop in inches, 7½; number of drops per minute, 93; screens made of brass wire; trade number of the screens, 50; tons of rock crushed in 24 hours, 33; tons crushed per stamp per 24 hours, 1.1; quality of the rock, soft; formation, limestone; fineness of the bullion, 990.

Silver-mill crushing wet.—Number of mortars, 6; discharge of mortars, double; number of stamps to each mortar, 5; total number of stamps, 30; weight of a stamp in pounds, 750; height of drop in inches, 7½; number of drops per minute, 87; screens made of Russia iron, punched; trade number of the screens, 6; tons of rock crushed in 24 hours, 47; tons crushed per stamp per 24 hours, 1.57; quality of the rock, soft; formation, limestone; fineness of the bullion, 990.

COPPER-MILLS.—The following is an outline of the process of copper-milling practised in the Calumet and Hecla, Allouez, and Atlantic mills in the Lake Superior region. For full details the reader is referred to a series of articles on "Copper-Dressing in Lake Superior," by T. Egleston, Ph. D., published in the *Metallurgical Review*, beginning May, 1878.

The rock as it comes from the mine is in pieces, varying from nearly a cubic yard in the conglomerate mines to fine dust. This is raised in the skip to the top of the shaft-house. The front wheels of the skip have a narrower tread than the hind wheels. The tramway at the top of the shaft-house is constructed so as to allow the front of the skip to drop and the whole contents of the car to be discharged over an iron grating. The large pieces fall to one side of this grating, the fine to the other. In front of the grating where the large pieces fall is the shaft-house proper. The rock coming from the mine is called the "ore." After passing through the mill the copper collected is called the "mineral," a term applied throughout the whole of Lake Superior to denote the dressed copper sent to the smelting works. After the ore is picked, the rich material goes to a car and is transported to the rock-house, where the car is dumped. The fine ore, passing the screens, falls into shoots or pockets, and the coarse ore goes to crushers. From the bins or pockets, the ore is discharged into the cars which carry it to the mills. After passing through the stamps, the rock is carried by launders to a head-box which discharges into the hydraulic separators, to be distributed to the washers. The ore from the stamp is discharged into the separator and falls by its gravity; it is prevented from at once going to the bottom by the undercurrent of water which it meets. The large pieces are caught first, and make their way out of the first slot, and so on until the fine is discharged from the last, a rough separation being effected in this way into four classes, each one of which is discharged from an opening made for the purpose by a launder on to the proper-sized screen of the washers below. Two or more sets of separators are used for each head of stamps.

The jig used is the Collom washer, in which the rapid movement of a plunger causes the water to rise up through the sieve, which causes the ore to separate by gravity. Whatever is fine enough falls through the sieve into a box below. The heavier material is distributed in the order of its gravity on the sieve, and the lighter portions escape over the apron. From the apron of one sieve the discharged material goes to the washer below. The different grades of copper, as they are separated from the upper sieves, are carried to the catch-boxes, usually indicated by the number of the grade of copper which they are to receive. The material which passes over the second row of washers is carried into settling-boxes in front of the catch-boxes, which are unequally divided. The ore coming from the coarsest sieve, being coarse, goes to a small compartment, and the ore from the

finest, being fine, to a large one. The long sides of the bottom of these boxes have a considerable incline, not more than a quarter of the bottom being flat. The overflow passes from here to the last pair of washers, from which the material goes to the beach.

The great difficulty in making the separation with these washers is to catch the light scale-copper, which is buoyed up by the water and floats off with it. It can be caught in blankets, but no practicable process has yet been found to clean the blankets. The float-copper can be saved, but it costs more to save it than it is worth. The number of washers per stamp is variable. At the Allouez mill there are 14 washers per stamp; at the Atlantic, 18¾; at the Calumet and Hecla, three stamps have 13 each and four have 21 each. The different grades of copper are all caught in the four boxes at the end of the single double set of washers, and the two at the end of the double single set, each of which is marked with the number of copper it catches. All the fine rock which passes the separator that is caught is buddled and tossed, and goes to a rotating slime-buddle, which is in general like the ordinary convex rotating buddle. Its peculiarity is the cam-shaped apron of the top, which revolves and covers the deposited copper, which is washed off only at the end of the rotation.

In most of the mills five grades of copper are made. No. 1 is usually coarse copper, which is picked out by hand, either directly from the ore or from the mortar of the stamp when it is opened for repairs, and is called barrel-stuff, as it is packed at once and does not go through the washers. Some of the mines, as the Atlantic, have no coarse copper, so that all grades go through the mill. At the Atlantic each of the first four grades goes through the same treatment; on the washers they sometimes make sub-grades of one-half, one-third, one-fourth, etc., but this is not usual. The following table gives the quantity and yield of the different grades at this mill:

No. 1 copper	90 per cent. ingot,	2 barrels,	1,500 to 1,600 lbs.
" 2 "	80 per cent. "	2 "	1,200 to 1,500 "
" 3 "	60 per cent. "	1 "	1,000 to 1,100 "
" 4 "	40 to 50 per cent. "	1 "	1,000 to 1,100 "
" 5 "	35 to 40 per cent. "	1 "	1,000 to 1,100 "

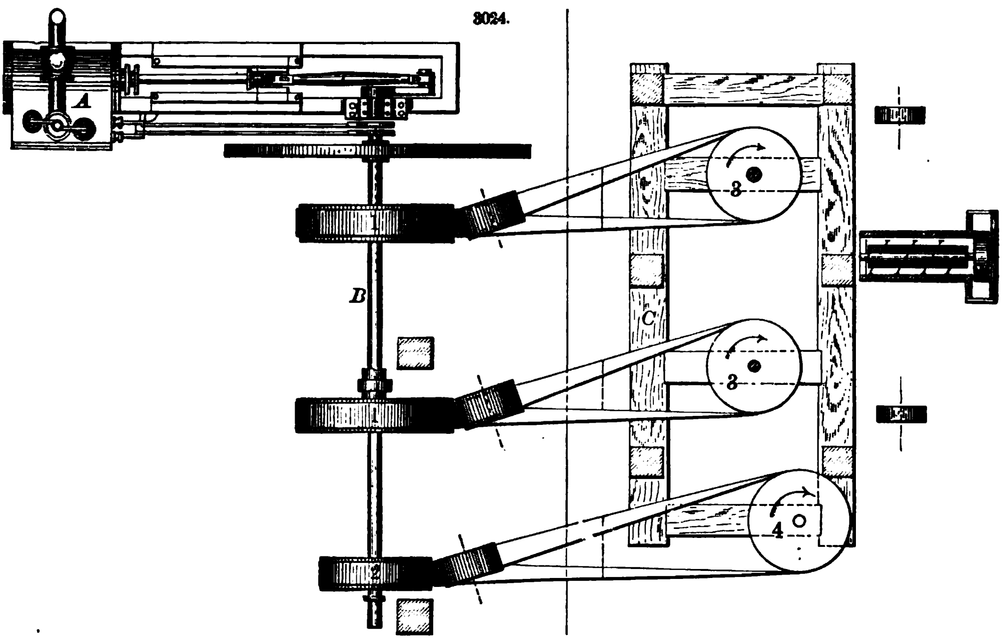
During the year the barrel-copper yields 78 per cent. of ingot. The rock from the mine averages 1 per cent., or about 27 lbs. per ton of rock. The cost of milling the rocks is 75 to 80 cents.

F. H. M. (in part).

MILLS, GRAIN. For the various processes of milling, see MILLING, GRAIN. See also MILLSTONES. The present article relates to the construction and arrangement of grain-mills, and the various forms of mills employed.

MILLING WITH STONES.—*Noye's Two-Run Mill*, of which Fig. 3024 is a plan and Fig. 3025 an end elevation, is an example of good modern American practice in the construction of portable mills. The various parts and number of revolutions are indicated as follows: *A*, engine, 12 × 16 in., 140

3024.

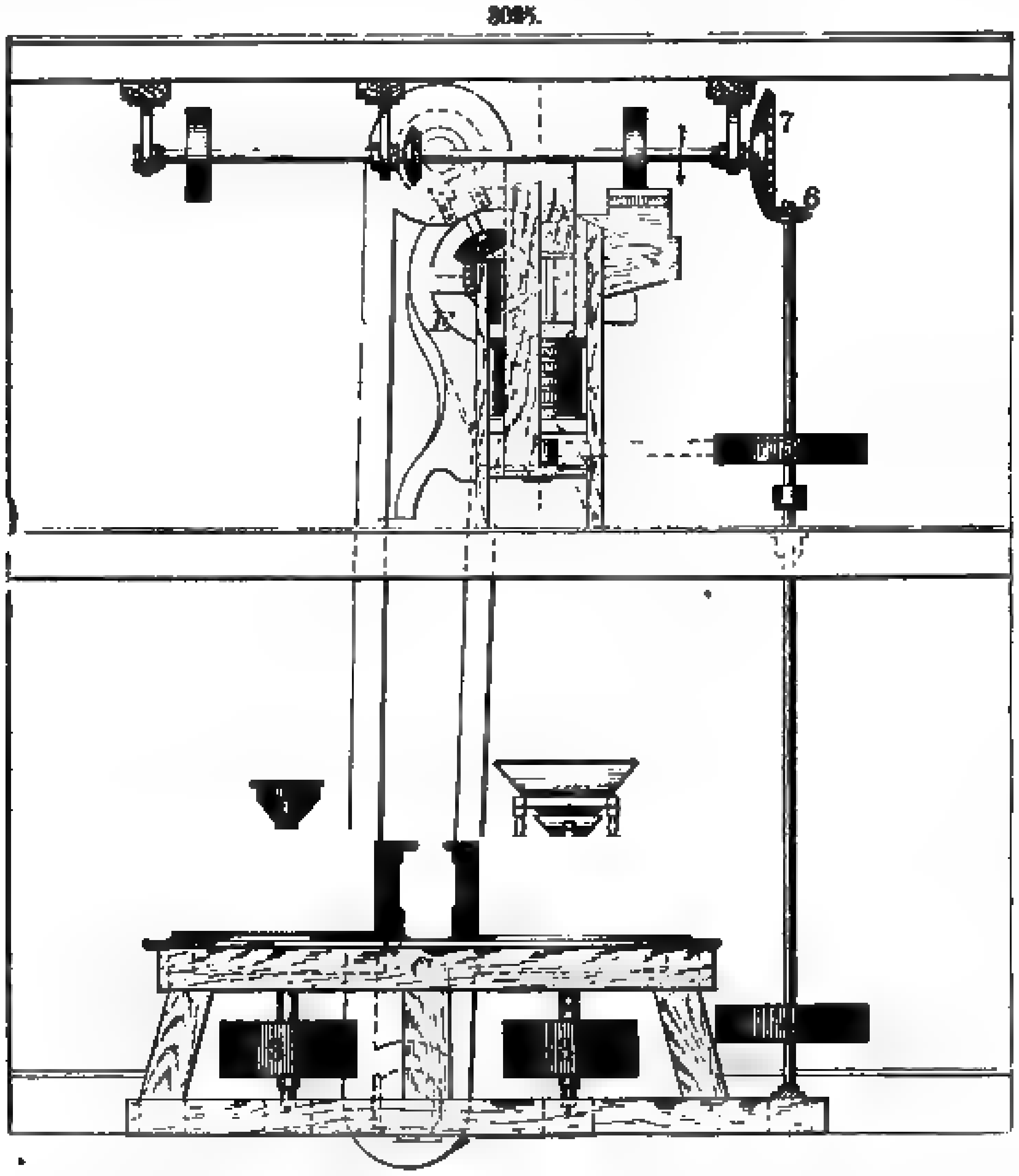


revolutions per minute; *B*, main driving-shaft, 140 revolutions; *C*, husk; *D*, upright smut machine, 700 revolutions; *E*, cylinder bolt, 30 revolutions; 1, pulleys driving stones, 140 revolutions; 2, pulleys driving upright shaft, 140 revolutions; 3, pulleys on spindles, 225 revolutions; 4, pulleys on upright, 144 revolutions; 5, pulleys on upright driving smut, 144 revolutions; 6, bevel-wheel up-

right driving line, 144 revolutions; 7, bevel-wheel on line, 40 revolutions; 8, cross-line driving elevator and bolt. The scale of these figures is 2 inches to the foot.

Fig. 3025 shows on the right the corn and feed stones, fed by a shoe and damsel. On the left are the wheat stones, fed by what is known as a silent feed. The grain first comes to the smut machine shown on the floor above the stones, and is cleared and dusted if it be wheat, and if it be corn it is

3025.



simply raised and cleaned by a blast of air. The grain then is conducted to the stones and goes through the process of grinding. The corn- and feed-stones are what are known as "open stock," while the wheat-stones are "close." After the corn comes from the stones it is put into bags and is ready for market; or if fine corn meal is required, a sieve is used, and at times a bolting-chest. The wheat after grinding is raised by the elevator and thrown into the bolting-chest *E*, where it is bolted and then put up for market. The plan view shows a system of reel-belt with tighteners. This system

is claimed to have many advantages, the first being that one run of stones may be stopped without the others, by simply slacking the tightener-pulley. A small conveyer is shown on this plan and on Fig. 3026, which is a large-bladed screw that moves the flour from where it falls from the stones to the front of the elevator.

Two-Run Mill in Portable Frame.—Fig. 3027 represents a two-pair, upper-runner, double-geared mill. The gears are of bevel-core pattern, the pinions having cut teeth and being fitted to the sleeves. A simple pinion-jack is attached to each pair, so that the pinion can be raised out of gear without

delay when it is desired to throw off one or both pairs of burrs and run the machinery. This figure also shows an upright shaft geared into the line under the mill, and designed to connect with the machinery on the floor above.

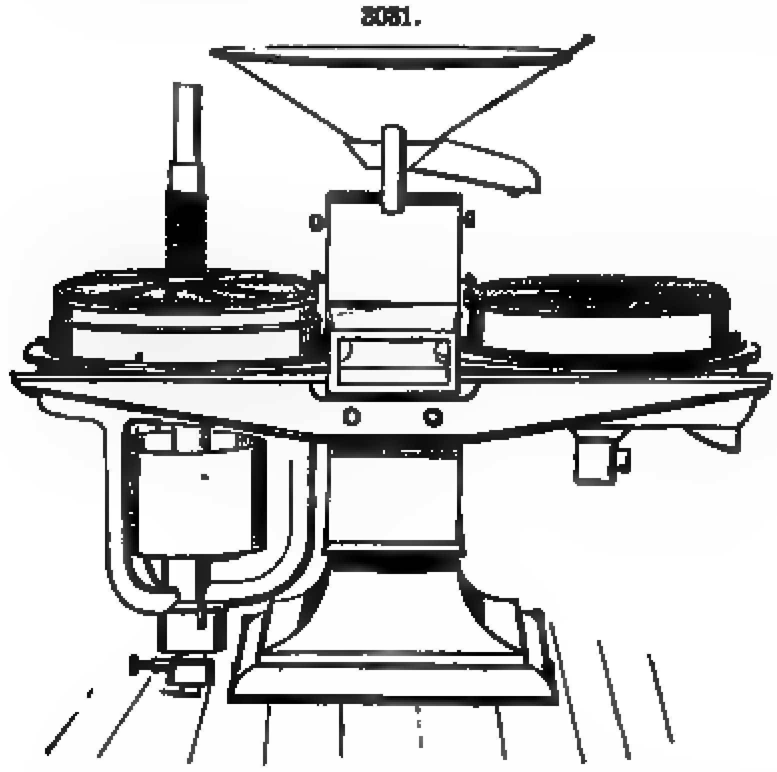
Munson's Double-Geared Mill is represented in Figs. 3028, 3029, and 3030. *A* represents a cast-iron frame, on the upper part of which is a cylindrical shell *B* to receive the runner *C*. A horizontal driving-shaft *D* has a bevel-wheel *E* secured to its end, which gears into a bevel-pinion *a* on a spindle *F*, the lower end of which is stepped in a socket *b*. This socket is fitted within an adjustable box *d*, which rests upon a lever supported by a nut and screw, by which means the stones may be made to run at a greater or less distance from each other to vary the fineness of the flour. The spindle *F* is provided with a collar *I*, Fig. 3029, which is fitted within a box *J* of cylindrical form, concentric with the shell, and within it there are placed bearings *h*. The collar *I*, within the box *J*, forms the bearing surface of the spindle. The tube *K* serves to supply the box with oil. On the upper end of the spindle *F* there is placed a clearer *L*. This clearer is formed of two arms, *p p*, attached to an eye *q*, which is fitted on the spindle and secured thereto by a feather and groove. *M* represents the driver, which is fitted on the upper part of the spindle *F*, and like the clearer is secured to the spindle by a feather and groove. *P* is a cast-metal cylindrical box, in which the upper stone *Q* is secured by set-screws. On the box *P* a hopper-frame *R* is placed, containing the hopper *S* and shoe *f'*, which may be arranged as usual.

3028. 3029.

Harrison's Mills.—Figs. 3031 and 3032 represent a standard heavy 20-inch mill, manufactured by Mr. Edward Harrison of New Haven, Conn., with which is combined a pedestal and temporary dressing frame, on which the stones may be dressed. The mill is thus rendered complete, and despite its high power is portable, requiring nothing to be built for it to rest upon. It is claimed that the grinding surface of this mill, at 1,400 turns per minute, is equal to three-quarters more than an old style 48-inch run at 175 revolutions per minute. The grinding capacity per hour is from 14 to 75 bushels, and the weight 1,250 lbs. Fig. 3031 shows the pedestal and case made in one casting, with a dressing frame bolted on and the burrs turned out upon it for dressing. The frame is made in two parts, which are fastened one on each side of the case by tap-bolts, the operation requiring but a few minutes. Mr. Harrison believes that no process

of milling can be perfect without the use of buhr-stones, and that such furnish the only proper grinding surface; that the stones should not be large and heavy, or horizontally superposed, or run at low velocity, but that on the contrary they should be light, hung vertically face to face, and driven at

3031.



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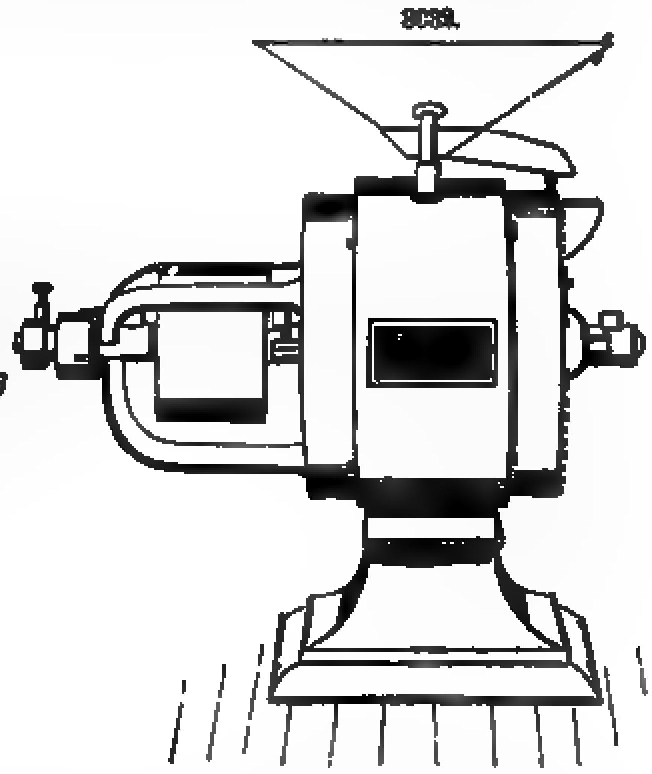


high speeds. In the former case there is mashing and over-grinding; in the latter there is neither, while high speed produces the necessary grinding surfaces.

Cylinder-Milling.—The cylinder or roller mill (*Walzenmühle*) of the Hungarians consists in its simplest elements of two small, parallel, horizontally disposed steel cylinders, placed near to each other, arranged for adjustment, and revolving from above toward each other. The cylinders in

the great Pesth *Walzenmühle*, the flour from which won the highest distinction at Vienna, were not more than 5 in. in diameter; the surfaces of some of them were traversed by numerous sharp furrows, or, which is the same thing, numerous sharp ridges parallel to the axis; others were smooth. Fig. 3033 exhibits three pairs of rollers, one above another, in a set, showing how the grain, in passing

from one pair of cylinders to the next, passes through an intervening body of air, and how the slight heat developed by the pressure between one pair of cylinders may be overcome by the cooling effect of the air through which it passes on its way to the next pair of cylinders. The smooth cylinders, revolving with uniform speed, if near enough together would crush the grain to flatness; if revolving with unequal velocity, the tendency would be to squash the grain; with grooved cylinders, the tendency is to indent and crack the grain where the velocity of the two cylinders is the same. Where the fluted or furrowed rollers revolve with unequal velocities, the action is frictional. The action depends as well upon their distance from each other as upon the character of their surface. If smooth cylinders are so far apart that the pressure is but slight, the berry will split open along the groove throughout its length, the two halves frequently clinging together, somewhat suggesting an open book; if the cylinders are nearer together, soft wheat will be flattened, hard wheat will be cracked into fragments, and the grits will be freer from bran than when obtained by grinding between stones. Fig. 3034 presents a profile of the grooved surface of a roller of large diameter. The essential advantage of the *Walz* or cylinder milling is that the product is *not heated;* it is a process of cold milling. It is also to be remarked that there is no dust-flour produced. In the great Pesth *Walzenmühle*, under the direction of Dosswald of the international jury, the wheat, before attaining its last disintegration, passed through from 18 to 24 pairs of cylinders.

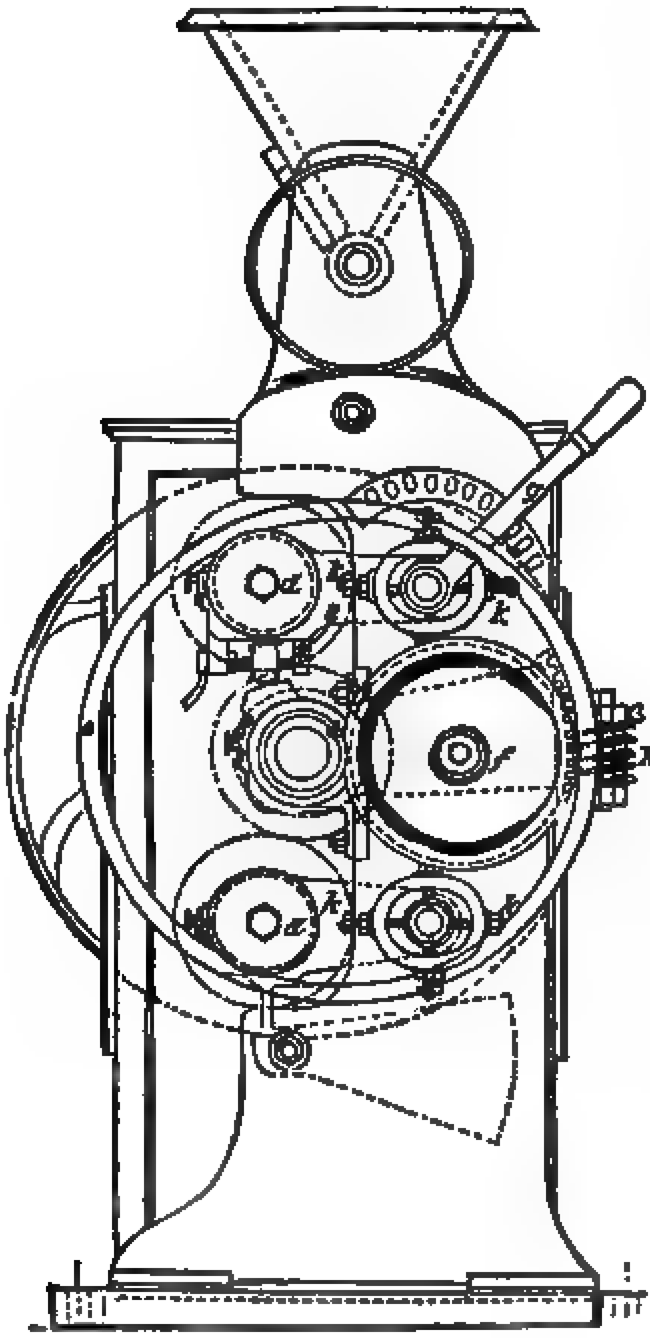
In Wyngaert's journal, *Die Mühle*, of December, 1874, and January, 1875, an account is given of an improved *Walzenmühle*, the work of an Italian inventor, Wegmann, in which the cylinders are of porcelain and the space between the cylinders controlled by springs (formerly by levers and weights), which, in the judgment of Wyngaert, promises to be of great value. Wyngaert says there is practically no heating of the product, and that the gluten retains its normal qualities; that the bran is subjected to no tearing process, but is flattened out, and the interior portion pressed away so that the middlings-purifier is rendered unnecessary; that the yield of first flour is greatly increased; that the effect of the adoption of the porcelain *Walzenmühle* on the low milling will be to change it to half-high milling; and the effect of it on high milling will be to reduce the number of grades of flour, a consummation greatly to be desired. Wyngaert sums up the advantages of Wegmann's porcelain-cylinder mill, as shown in a series of special experiments undertaken at his instance and under his direction, as follows: 1. It renders unnecessary the whole system of grits and middlings-purifiers. 2. It secures a larger proportion of clear, pure flour. 3. It makes it impossible to injure the quality of the flour in milling. Fig. 3035 is a sectional view of the porcelain-cylinder mill. *a a* are the feed-cylinders; *b b*, the porcelain cylinders; *c c*, the scrapers with glass edge.

The Ganz-Mechwart Roller-Mill.—In 1878 Mr. Andreas Mechwart of Buda-Pesth, Hungary, patented in England a new roller-mill in which the bearings are so arranged that the rollers may be removed separately and without the necessity of taking any other portion of the machinery to pieces. In order to cause the swing-rollers to exert the necessary pressure on the middle roller without transmitting that pressure to the bearings, their shafts carry on either side of the frame a small ring, on which a large hoop is sprung so as to embrace the two rings with the requisite pressure, while they cause the hoop to revolve by their rotation. When necessary the pressure exerted by the inherent elasticity of the hoop may be increased by causing a pulley, suspended from an oscillating lever, to bear against the inside face of the hoop with a pressure determined by the compression of a coiled or other spring or weight at the opposite end of the lever.

Fig. 3036 represents an improved form of mill constructed in accordance with the foregoing principles. It embodies an arrangement by means of which all the pressures exerted on the rollers are resolved within the ring, the surfaces which transmit the pressures one to the other being made to roll one upon another, and hence no power is lost through friction. Here the middle roller-axle is furnished also with friction-wheels *d*, between which and the steel ring *c* a fourth friction-roller *f* is inserted, that turns on a bolt projecting from a toothed sector centred, or rather pivoted, on the middle roller-axle bearing, and gearing into a worm *X*, which adjusts the position of the friction-wheel *f* around the middle roller-axle; and since the ring centre does not coincide with the axis of this roller, it determines the eccentricity of the ring, which again regulates the pressure exerted on the outer rollers or friction-wheels *d d*. In order to provide a means for adjusting the pressure simultaneously on both sides of the machine, the bolt on which the upper swinging roller oscillates is cranked, so that the lever *g* is moved upward, the axis of oscillation is advanced, and, since the friction-wheel *f* on each side of the machine holds the rings from following, the pressure exerted by the ring is again increased, but in this case, as previously stated, simultaneously on both sides. To neutralize the weight proper of the bottom roller, balance-weights are provided. The bolts on which the exterior rollers swing are set between horizontal and set screws *k k*, and determine the parallel adjustment of the rollers, rigorous parallelism being of the utmost importance. The feed-hopper is of the usual form, but the feed on leaving the feed-roller is divided by narrow alternating channels into two currents, one of which being led to the top pair of rollers, after being crushed, is delivered through vertical channels in a cast-iron scraper, while the other half feed, traversing channels in the same casting, but alternating at right angles, or nearly so, with the first, is crushed between the lower pair of rollers. The driving-pulley is keyed on the middle roller-spindle, and has to make 180 revolutions per minute.

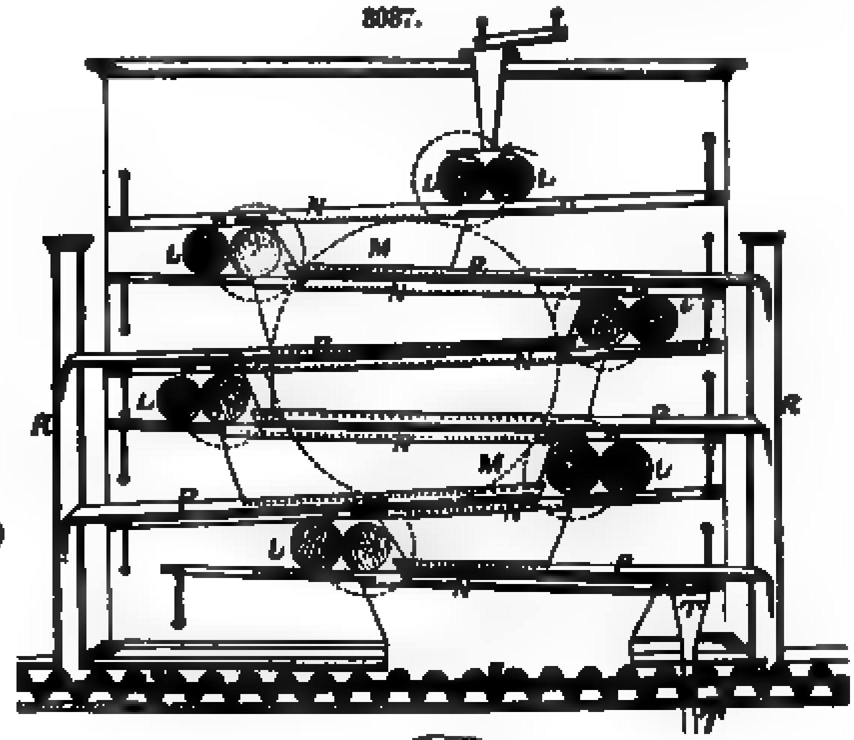
Buchholz Cylinder-Mill.—There has appeared in England a combination of the grinding and bolting processes which is of much simplicity. The cylinders, Fig. 3037, revolve with unequal velocity, and are all set in motion by a single large cog-wheel *M M*. The pointed and purified grain is fed in between the highest pair of rollers *L*, to be cracked as it passes through into coarse fragments, and more or less flour, grits, and bran, which are received upon the inclined shaking-sieve *N*, where they are sorted, the grits and fine flour passing through to the trough *P*, to be discharged into the upright receiver *R*. The groats and bran pass on to the next pair of rollers, to be further reduced to finer groats, grits, flour, and bran. Falling upon the second sieve, the flour and grits

3036.



3039.

3037.



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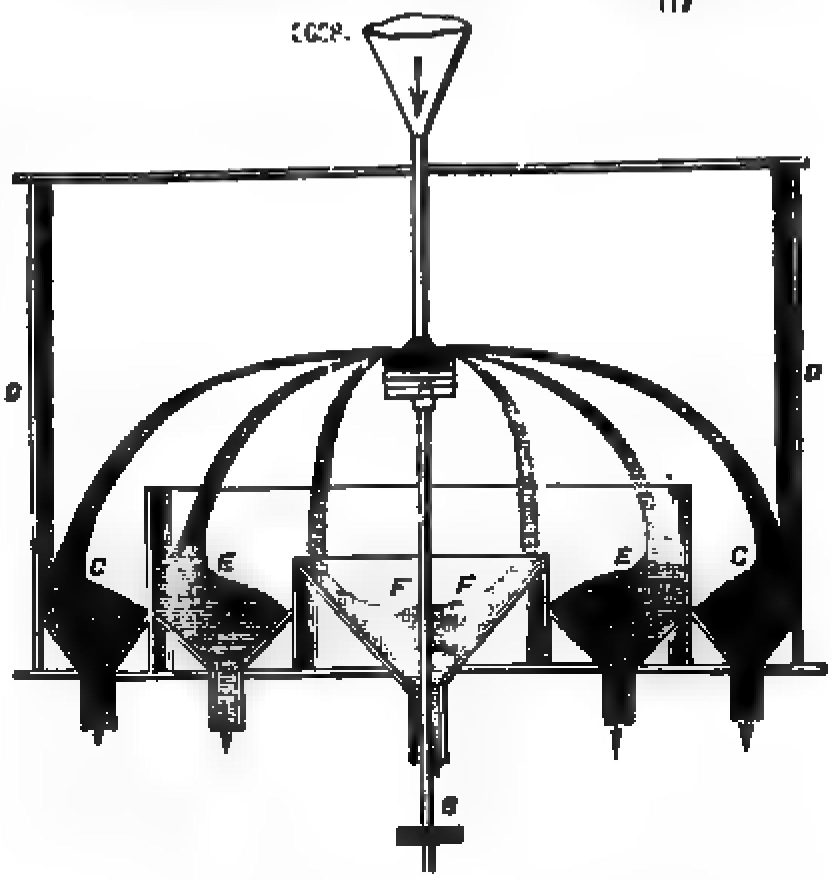


3040.

pass through to the trough P, while the bran and groats pass on to the next pair of rollers, and so on until, the groats having been reduced to grits and flour, all the bran is collected in $T\,T$, and all the flour and grits in $S\,S$. The screw conducts the flour and grits to a bolt, where the flour is bolted off, and the remaining grits graded in the centrifugal machine, Fig. 3038. In this a small horizontal wooden disk A, on the vertical spindle B, is made to revolve at such a speed as will throw the semolina to the sides C of a cylindrical case D. The bran, being lighter, is not thrown so far, and hence falls into an inner annular division E of the case, while the fine dust falls into the centre compartment F, and all are collected separately on a lower floor from the spouts. The speed of the disk A varies from 250 to 650 revolutions per minute.

Milling by Disintegration.—Thomas Carr's disintegrating flour-mill is shown in Figs. 3039 and 3040. It consists of a pair of circular disks, a and b, rotating in contrary directions upon shafts d and e. The opposing faces of the disks are studded with a series of short projecting bars, arranged in successive concentric rings or cages, and the rings fixed in one disk intervene alternately between those fixed in the other disk, and revolve in the opposite direction. The grain is delivered down a fixed shoot g into the innermost cage, from which it is instantly projected through the machine, being reduced almost instantaneously to the form of meal by being dashed from right to left alternately by the bars of each of the successive cages as the same rotate at very high speed. The machine is driven at a speed of about 400 revolutions per minute, and the outermost ring being 6 ft. 10 in. in diameter, the last beaters have a velocity of 140 ft. per second. This is double the velocity, and consequently gives four times the force of blow, of the innermost ring of beaters, the force of the blow being proportionate to the square of the velocity. It is claimed that the whole power employed is usefully expended in pulverizing the material, excepting only the portion of the power absorbed by the resistance of the air to the rotation of the beaters. A machine of this kind 7 ft. in diameter has disintegrated 160 bushels of wheat regularly per hour. Kick's Vienna report, after analyzing the work of this mill, gives it a secondary place as compared with the work of the high milling with runs of stone or the cylinder-mill. The cylindrical body to which the radial arms or beaters are attached should be of sufficient length to come within a few inches or so of the interior portions of the sides of the casing. The case may, for example, be 4 ft. in diameter and 1 ft. long, the shaft which drives the interior mechanism passing through the casing on both sides. The mill is set after the manner of the Carr mill, but the delivery is sidewise and not circumferential.

The Carr-Toufflin Disintegrator.—This is essentially the same as the Carr apparatus previously described, the improvement being means for maintaining a vacuum within the case. The grain is fed into a hopper, and thence passes to a cylinder divided into several approximately air-tight compartments by radial partitions attached to a shaft passed through the centre of the cylinder, and caused to rotate by a pulley driven by a belt connected to the main driving-shaft. As each compartment is presented in turn to the aperture at the bottom of the hopper, it is filled with the grain or other substance to be pulverized or reduced; and as it continues to rotate, it carries the same round to the aperture on the top of the feed-pipe, into which its contents are discharged, while all air except that which is contained in the interstices of the grain or granules is effectually excluded.

The Vapart Disintegrator, represented in Fig. 3041, consists of three horizontal platforms keyed to a vertical shaft. The platforms are fitted with vanes placed radially. The shaft is supported below by a foot-step, and above by an ordinary bearing. The platforms are inclosed in a cast-iron cylindrical casing, fitted with two doors to give access to the interior. Between the platforms, and attached to the casing, hoppers are fixed to deliver the material to the centre portion of the platforms, and opposite the platforms serrated segments of chilled cast iron or steel are attached. The shaft and platforms are made to revolve rapidly, and the material is first delivered into the machine near the centre of the first platform, where the velocity is low. It is then guided by the vane, and by centrifugal force is projected violently against the first series of segments. The broken material falls by its own weight down the first hopper to the centre of the second platform, and is again thrown violently against the second series of segments, and afterward against the third, when the material finally falls out of the machine in a thoroughly disintegrated state. Two arms fixed under the last platform serve to keep the machine clear. The pulverized material can then be led away on a belt or otherwise, as may be convenient.

American Disintegrating Processes.—The Carr disintegrating mill has been much improved by several American inventors, who have practically shown that grinding by disintegration may be carried out, and, when such form of grinding is combined with the proper processes, can produce as good flour as any other system. The disintegrating mill as now made consists of a heavy iron casing like that of Carr, but within which revolves a solid short cylindrical body, to the periphery of which are attached 4 or 6 radially projecting beaters, the outer portions of which beaters revolve but a very

short distance from the interior of the circumferential portion of the casing. The grain is fed into the mill at the side as near the centre as possible, and is delivered also from the side as near the circumference as possible. This side delivery is very important, and is a great improvement over the circumferential delivery of mills like Carr's. The grain being reduced has a tendency to fly away from the centre, whatever its size; and if the mill has a circumferential delivery, much grain only partly ground may thus escape. When the delivery is at the side, however, the particles are carried from their plane of motion only when small enough to be moved therefrom by the circulation of the air through the mill. So long as a particle of grain is of sufficient size and has weight enough to keep itself in its plane of motion, it will not be deflected, but will remain in the mill, and a further reduction will take place; but so soon as it is small enough, the air-current will exert a force upon it sufficiently powerful to overcome its tendency to continue moving in the same plane, and it will be delivered through the side opening at right angles to its previous plane of movement. By regulating the amount of air which is permitted to enter the mill, the fineness of the product may be controlled. The stronger the blast, the coarser will be the product; the less the air, the finer the product. From one mill of this character the product is generally passed into another one moving more rapidly, and sometimes into a third moving still more rapidly; and in this way a gradual reduction is effected.

FLOUR-MILL PERFORMANCES.—Messrs. Prescott, Scott & Co., of San Francisco, have deduced from a number of examples the following as the average performance of flour-mills in this country per single run of 4-foot stones:

Number of revolutions of the stones per minute	250
Bushels of wheat ground per hour	20
Barrels of flour dressed per 24 hours	110
Percentage of extra flour	0.68
Horse-power per single run and dressing machinery	45
Pounds of coal-screenings per barrel	45
Cost of fuel per barrel in cents	18
Pounds of coal per horse-power per hour	5
Horse-power required to make one barrel per day	0.5

MILLS, GRINDING (FOR VARIOUS SUBSTANCES). There is a large number of mills of special construction designed for grinding paints, stone, fertilizers, and other substances. The various forms of grain-mills are utilizable for these purposes, and in the majority of cases ordinary stone-mills, or those constructed on the disintegration principle, are in fact used. It seems proper, however, to recognize as a distinct class those types of mill the use of which is confined to particular substances, and does not extend to grain-grinding. Several examples of these machines are therefore presented.

3042.

Ball-Mills are those in which the material treated is pulverized by heavy metal balls. Fig.

3042 represents an ore-grinder on this principle manufactured by the Lane & Bodley Company. It consists of a perforated cylinder surrounded by two screens, and containing a number of balls of different diameters. Spiral conveyers are provided, which return the particles that are too coarse to pass the screens to the interior of the cylinder, where during the rotation of the latter they are again acted upon by the balls. The ore is moved forward through the hollow journals into the rotating cylinder by a reciprocating piston or plunger working in a feeding chute opposite one of the journals.

Fig. 3043 represents an excellent form of ball-mill used for the grinding of graphite. *A* is a heavy iron saucer-shaped receptacle, having an aperture in the centre, across which extend arms, connecting it to the central shaft *B*. This shaft is rotated by the pulley shown in the direction of the arrow. Above the saucer is a disk *C*, in which are four recesses. In these recesses, and resting on the saucer below, are four 32-lb. cannon-balls; and attached to the middle of the disk is a sleeve *D*, inclosing the shaft *B*, and carrying a pulley, by which it is rotated in a direction relatively opposite to that of the shaft *B*. A casing surrounds the mill, and through this casing at its centre the graphite enters, emerging below through the funnel *E*, whence it is taken away by an elevator. When the graphite enters, the centrifugal force generated by the swiftly rotating parts throws it outward so that it may be at once acted upon by the balls. Wear by the latter on the disk is prevented by the steel pins *F*. It will be obvious that under this condition the heavier particles of the material will approach nearest the circumference, while the finer ones will arrange themselves in the order of their weights toward the centre. Consequently the finest-ground graphite will always be that which is escaping from the mill, while the grinding parts constantly act on the coarser portion. The substance really, therefore, is ground but once, and there is no grinding and regrinding of already sufficiently pulverized material. In this way the grinding operation is greatly facilitated, and at the same time the graphite is reduced to a degree of fineness unattainable in the ordinary forms of mill.

3043.

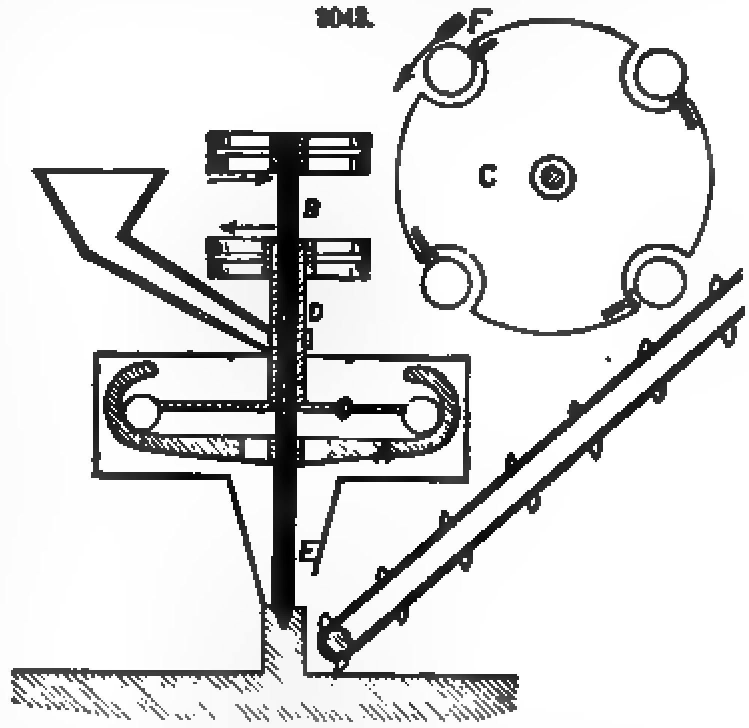


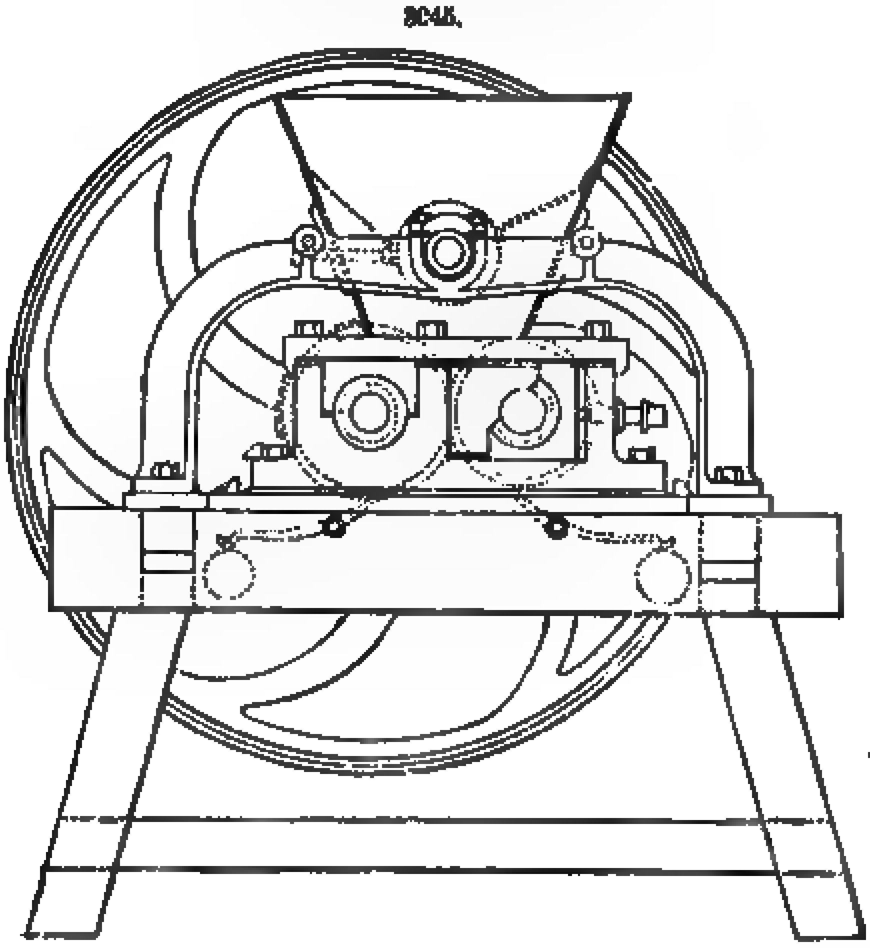
Fig. 3044 represents the bullet-mill of M. Hanctin. It consists of a hollow cylinder, in the periphery of which are holes which receive bullets as shown. The bullets are perfectly free to move, and are disposed in spiral rows. The cylinder is mounted on an iron axis, and is rotated within an inclosing cylinder, the ends of which are closed. The material to be ground is introduced between the two cylinders, and is pulverized by the action of the bullets. It will easily be seen that as the bullets are placed in spirals, there is no point of the interior of the envelope with which they do not come in contact, so that none of the material to be ground escapes their action.

Oil-Mills.—In the manufacture of oil from seeds, the first operation consists in separating them from all foreign matter, so that they may be perfectly clean and free from all sticks and dirt when fed into the crushing rolls. This operation is accomplished by passing them through a shaker, and then through an exhaust-fan in the same manner as for the cleansing of wheat. When the seeds have been thoroughly cleaned, they are fed into the hopper of the crushing rollers, which are illustrated in Fig. 3045. The machine has two rollers of unequal diameters, which are set parallel and in the same horizontal plane. The bearings of the small roller are adjustable, so that the space between the two may be varied. A scraper bears against the lower side of each roller, and is kept in contact with it by a counter-weight. Over the rollers is set a sheet-iron hopper, with a feeding roller running through its middle. The amount of feed is adjustable by a movable plate regulated

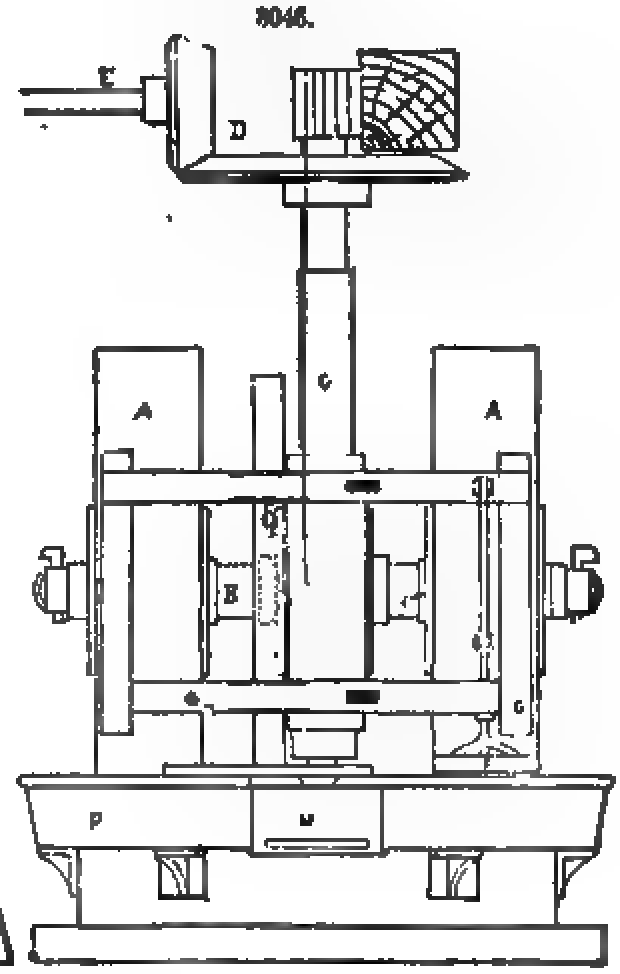
by a screw-bolt. Two large pulleys on the shaft of the large roller, one tight and the other loose, give motion to the machine. The large roller drives the small one by spur-gearing at one end.

After the seeds have been crushed, they are ground under a pair of edge-stones, the total weight

3045.



3046.



of which is about seven tons. In Fig. 3046, *AA* are the stones, running with their edges on a bed-stone. The bed is encircled by a curb *P*, which has a mouth *M*, through which the meal of the ground seeds is discharged. Scrapers *F*, hung on the frame *G*, follow the stones, and strike off the ridges into the path of the advancing stone. The stones run loose on a shaft *B*, which is held in a slot in the vertical shaft *C*. The shaft *B* can rise and fall in the slot, to accommodate itself to the varying thickness of seeds under the stones. Motion is transmitted from the motion-shaft *E* by the bevel-gearing *D* to the upright shaft *C*. The seed is generally ground under the stones for about 25 minutes, at the end of which time it is ready to be transferred to the heating pans.

3047.

Crushing Mills for cements, phosphates, coal, &c., are commonly made in the forms shown under BREAKERS OR CRUSHERS. Edge-rollers of metal constructed as shown in Fig. 3046 are largely employed in the preparation of chocolate and pharmaceutical products. An improvement on these machines has been devised by M. Hanctin of Paris, and is illustrated in Fig. 3047. It consists in forming the surface of the rollers with deep channels or grooves, the salient edges of which alone perform the grinding. The rollers are so placed on their arbor that the ridges formed in the material by one are immediately divided by the projecting edges of the other as the rotation continues. The advantage of this arrangement is that the cutting edges constantly penetrate the material and prevent its caking, and also tend to distribute it evenly around the bottom of the receptacle.

MILLSTONES. *The Stones.*—The buhr-stone is a form of silica which occurs in great masses. Its texture is essentially cellular, the cells being irregular in number, shape, and size, and are often crossed by thin plates or coarse fibres of silex. The buhr-stone has a straight fracture, but it is not so brittle as flint, though its hardness is nearly the same. It is feebly translucent; its colors are pale and dead, of a whitish, grayish, or yellowish cast, sometimes with a tinge of blue.

The surface of the stone (Fig. 3048) is technically made up of the *eye* (*n*), the *bosom* (*x*), and the *skirt*, or outer margin or edge. *Dress* is a system of lands and furrows, whereby the *face* or grinding surface of the stone is prepared. *y*, Fig. 3048, is a section of the stone dress, consisting of a *leader*

t and its branches. The grooves which expedite the grinding action are termed *furrows*, and the level surface between the latter the *lands*, *x*. *v* is the *skirt furrow*, and the branch furrow nearest the eye of the stone is called the *second furrow*, *u*. Referring now to Figs. 3049 and 3050, which represent a simple form of mill for purposes of explanation, *a* is the bed or stationary stone, *b* the runner or upper revolving stone. A pair of stones in running order is called a run of stones. *d* is the spindle or shaft which supports and drives the runner. *e* is the *step* or *ink* which holds the toe of the spindle, and is supported by the *bridge-tree*. The *bush* or upper bearing of the spindle is shown at *g*, and it is fastened on the bed-stone by keys *h*. The *driver* *i* is a cross-bar whereby motion from

3048. 3050.

3049.

the spindle is conveyed to the runner, sockets or coffins in the eye of the latter receiving the ends of the driver. For poising the runner on the spindle the *balance rynd* *j* is used, and on the under side of this is the *cock-eye* to receive the spindle-point, or *cock-head*. *o* is the *hoop* or inclosing case of a run of stones; *p*, the *hopper* or conveying trough; *q*, the conducting *spout* from hopper to eye of stone; and *s*, the *damsel* or projection on the millstone-spindle for shaking the shoe. The *wing* 1 is a strip of leather attached to the skirt of the runner to sweep the ground meal into the spout. The *lighter-screw* 2 serves to adjust the relative distance of the grinding surfaces, and the *husk* 3 is the supporting frame of a run of stones.

Selection of Stone.—A medium stone is preferable, not too porous or open, and neither extremely hard nor soft, and of medium grit. No stone will do good work which is composed of blocks of uneven quality. If a close stone is preferred, select one that has every block close alike; if an open porous stone is wanted, the same rule should govern; but in no case select a stone the openings or porous parts of which exceed one-tenth of the whole face.

*Dress, Width of Furrow, and Draught.**—For high grinding a dress is preferable in which every furrow runs to the eye, and in no case should a dress be used which makes less than every other furrow a leading furrow. The *depth of furrow* should be three-sixteenths of an inch at the eye and one-sixteenth to three-thirty-seconds at the skirt. The depth, however, depends largely on the kind of material to be ground, the degree of fineness to which it is to be reduced, and the evenness it is to have on being discharged. Great care should be had in furrowing a stone, particularly bed-stones, to have all the furrows of equal depth and width at the eye; otherwise uneven work will result. As regards *width of furrows*, they should be wide enough to insure the stone grinding perfectly cool and to discharge the chop free and round. With stones grinding on winter wheat, the furrows required are equal to very nearly two-thirds of the entire surface of the stone. The *draught* can be decided only when the dress to be put in, the amount of grain to be ground per hour, and the speed and diameter of burrs and quality of stone are considered. Mr. Gent states that with a medium close stone, 4 ft. in diameter, at a speed of 130 revolutions per minute, to grind $5\frac{1}{2}$ to 6 bushels per hour, every furrow leading to the eye, $3\frac{1}{2}$ in. would give a fair result. With regard to the *face* of the stone, the eye-blocks should be a little below, so that the redstaff should touch the whole face and show heaviest at the skirts. Both face and furrow should be as smooth as they can be made without destroying the grit of the stone. If the proper amount of wheat by actual measurement is being ground, and the stone heats and glazes, the remedy is to take it up and widen the furrow until it will grind the proper amount cool.

3051.

Fig. 3051, from Kick, illustrates an approved form of groove, the arrow showing the direction of motion of the upper stone. It will be seen that the pulverized grain, as it accumulates in the trough *a b c*, will be pushed up along the surface *b c* to the summit of the finely-grooved land beyond, where it will be subjected to trituration till it reaches the next furrow, from which it will, as the furrow

* From report of J. F. Gent, previously quoted (page 337). See *The Miller and Millwright*, v., 9.

fills, be forced out on to the succeeding land. The pulverized or ground grain is discharged from the skirt under the influence of the centrifugal force, the velocity of its movement increasing with the distance from the centre. This velocity may be checked by nearing the stones to each other, or by the conformation of the furrows toward the periphery.

Fig. 3052 is a copy of the face of the stone of the Thilenius mill at Cape Girardeau, Mo., which produced the flour exhibited at the Vienna Exposition. The stone is 4 ft. in diameter; cutting surface, 13 quarters; fine grooving (skirt) extends from 10 to 12 in. from the periphery, and has from 30 to 35 cracks to 1 inch; bush, 10 in. square; spindle, 4 in.

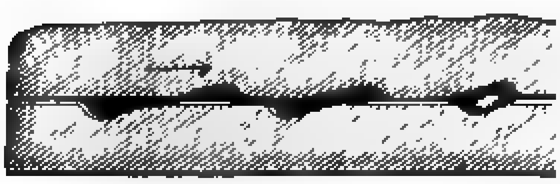
3052.

Fig. 3053 exhibits a grain of wheat about to be cracked and crushed by the movement of the upper stone. The motion from left to right will carry the fragments up the inclined plane to the land, where they will be reduced to a size determined by the distance apart of the stones.

Fig. 3054 represents Munson's machine-balanced millstone. This is provided as shown with cast-iron eye and S-shaped driver. The engraving shows clearly the method of equalizing dress.

The Redstaff and Proof-Staff.—To obtain the best results from a grinding-mill, it is necessary that the cutting edges of the millstone be dressed to the greatest attainable degree of truth. This is accomplished by means of a piece of metal having a true and straight surface, and termed a paint- or redstaff, its surface being covered with a red paint which when applied to the surface of the stone will mark the projecting spots thereon. It is obvious that from contact with the stone the surface of the paint-staff soon gets out of true; hence what is termed a proof-staff is employed. This consists of an iron surface made as true as possible, and kept for the sole purpose of a guide or proof-gauge whereby to true up the paint-staff. A full description of the proper method of truing proof-staffs is given under the head of PLANOMETER.

3053.



3054.

MILLSTONE FITTINGS.—The *damsel* is shown separately in Fig. 3055, and is placed as shown more clearly in Fig. 3056 at *A*. By its rotary motion and irregular shape it vibrates the shoe, and so feeds the grain to the stone. Damsels are made with either three or four ribs. The four-ribbed damsel is used for 4-ft. stones, and the three-ribbed for stones of 3 and 3½ ft. diameter. The material is usually polished cast iron. Wrought-iron 5-beater damsels are also constructed, and for small stones a pipe damsel is employed. The *arched bridge-pot*, represented in Fig. 3057, is used for straddling the driving-shaft when bevel-gear is employed. This same figure also shows the arrangement of the *yoke-lever*.

Fig. 3056 shows the arrangement of an improved system of fittings constructed by Messrs. John T. Noye & Son of Buffalo, N. Y. *A* is the damsel, which is made with a tenon on its base, which fits into a mortise on the top of the bail *B*, so that it partakes of the motion of the bail. This bail is

set into the stone, and is fixed. *C* is the driver, which is of cast iron or steel, as the case may require. It has in its centre a slot, which is planed out so that true sides are parallel. Into this slot the top of the spindle comes, and is seen in the figure finishing in a cone-shaped apex. The driver has also two lugs on each side about 1½ in. apart, between which the bail slides. The "cock-head" is made of steel and set into the top of the spindle, in the same way that the steel toe is set in the lower end of the spindle, as shown in Fig. 3058. In Fig. 3056 the cock-head is made out of proportion in order to show it more clearly. This cock-head is received by the "cock-eye," which is placed at the top of the under side of the bail, and in fact the weight of the stone rests upon these two parts. *D* is the spindle, which is made of cast or wrought iron as desired, a proper change being made in the diameter for each condition of the iron. At the base there is a steel toe fitted as shown in Fig. 3058, on which the weight of the stones and spindle is supported. At *E* are back-lash springs, which receive the strain when the stones run ahead of the engine, and so prevent sudden jars either in starting or by irregular feeding. These springs are of wood, and are bolted to iron arms which are keyed to the spindle. The wood springs are pressed against by the two pins *F*, which are made fast to the pinion *G*. This pinion is held in its position by a ring of wrought iron which is supported by the two rods *H*, and which are raised and lowered by means of the hand-wheel *I*, so as either to drop the pinion or raise it into gear by means of the lever *J*, tightener-screw, and bevel-wheel *K*. *L* is a movable part of the tramp-pot called the "oil-pot," and is made to move in any direction by set-screws shown. The object of moving this oil-pot is to keep the spindle plumb at all times. The bottom of this oil-pot is made of steel to prevent wear.

3055. 3056.

Fig. 3058 represents a hollow-head spindle used for upper-runner portable mills. The grain is fed from a hopper and shoe by means of a stationary tube through the head of the spindle, and falls upon the face of the bed-stone, upon which it is distributed by the centrifugal force of the spindle. This serves to prevent the grain and other stuff ground from hanging in the eye.

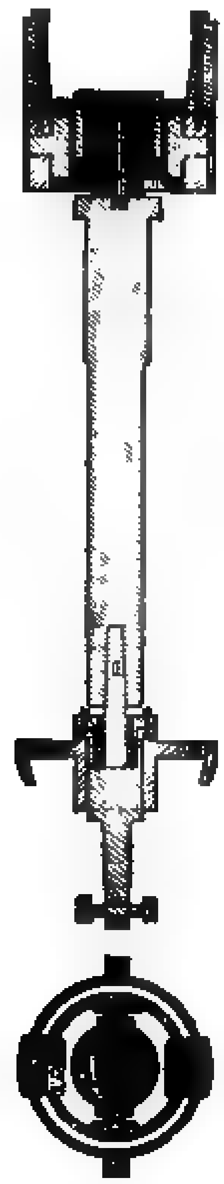
Mill-Picks are usually made of cast steel hardened and tempered in anthracite forges. If the tool is of English steel, it should be forged at a moderate red heat, but not hot enough to scale. It should not be hammered after it has lost its redness. Heat to a low red heat; then for hardening dip the tool in salt water slightly tepid, and temper it to a brown. If American chrome steel is used, heat to a yellowish color for forging, to a low red for hardening, and quench right out. Mill-picks should weigh from 2 to 3 lbs., and in grinding them the pressure should be moderate and plenty of water should be used. Do not grind to a feather-edge. Figs. 3059 and 3060 represent Noye's improved pick and holder. *A* is a hollow cylinder having both ends closed, and is slightly oval, the longer axis being in the direction of the handle. From one side of the shell of this cylinder is cast a suitable socket for the reception of the handle, and midway on the circumference, between the socket and the point opposite, are formed slots for the reception of the pick *C* as shown, the upper one being smaller than the lower one, to correspond to the taper of the pick. Before the pick is inserted, two semicircular blocks of wood, *B*, are put in through the lower slot. These are secured by a small rivet, but are left free to move their inner straight face, accommodating themselves to the taper of the pick, whatever that taper may be; when the latter is inserted it thus holds picks of various tapers securely and firmly, and at the same time can be adjusted to any desired bevel to suit the operator. In using the holder, the pick is placed between the blocks and adjusted to the desired bevel. The hand being placed on the pick, a light blow is struck on the stone, and the holding of the pick is thus secured in the desired place.

Ventilation of Millstones.—The ventilation of millstones aims, by means of introducing air between the grinding surfaces of the burrs, to keep the chop cool and prevent injurious heating. The ventilation can be accomplished by forcing in or sucking out the air between the grinding surfaces with the help of a forcing or exhaust ventilator; or channels may be employed in the runners, which, narrowing from above downward, penetrate the stone in a diagonal direction, end in a slit on the surface of the stone, and, by the movement of the burr, introduce air between the faces; or,

lastly, it is sought to introduce the necessary quantity of air by means of pretty deep furrows on the face of the burr. The short furrows also serve this purpose in part, and are rightly called air-furrows. The quantity of flour produced is said to be largely increased by ventilation. The various kinds of

3037.

3038.



ventilation are as follows: 1. The introduction of air by means of a pumping ventilator into the eye of the runner, and thence between the grinding surfaces of the burrs. 2 The use of suction ventilators, by which the air is exhausted from the eye of the runner toward the skirt. This arrangement requires that the apartment about the burrs be air-tight, and open at the eye of the runner, and the

discharge spout must be air-tight. 3. A combination of exhaust and pumping ventilators. 4. The introduction of air between the grinding surfaces of the burrs by means of air-channels or slits in the runner. Ventilation by mingling a current of air with the pulverized grain tends to restore the

normal temperature. This principle is applied on a larger scale after grinding, where mechanical appliances are introduced to stir the meal and continually bring fresh surfaces in contact with the air. The familiar hopper-boy, which is a sort of great rake, so operated as to stir up a layer of meal of moderate depth, is largely used for this purpose.

Diamond Millstone-Dressers.—Numerous machines have been constructed for dressing millstones by the aid of the black diamond or carbon. (See DIAMOND.) A machine devised by M. Millot of Zurich, Switzerland, has a rotating cutter, which moves forward and back. When it has completed its travel in one direction, a ratchet-wheel advances one tooth, and the machine operates so as to present a new surface of the stone to the action of the diamonds. The cutter-head revolves at the rate of 12,000 turns per minute. The diamond-points work in oil, and the adjustment is such that they always fall into the old series previously cut. But very little power is required, and a simple cord serves for its transmission. It is also stated that stones dressed by this means will last longer than hand-dressed stones. (See *Scientific American*, xxxv., 383.)

In another machine in which diamonds are used, the stone is clamped on a face-plate, and the tool, containing eight diamonds and revolving 3,500 turns per minute, is mounted on a carriage, which travels on slides across the face of the stone. Means are provided for revolving the stone so as to present different portions to the action of the tool.

Fig. 3061 represents Griscom's diamond millstone-dresser in section. It consists of a plain cast-iron bed, upon which a carriage supporting a black-diamond-pointed tool is fitted in guides, which allows it a stroke the length of a land; and to this carriage is attached an automatic device which feeds the diamond-pointed tool each stroke until the width of a land is traversed. It is then quickly set back to its original position by means of a coarse screw, and is again ready to work. The depth of the cut is regulated by a screw attached to the tool. *A* is the adjustable plate, shown encircling the stone in Fig. 3062; *B* is the bed-plate; *C*, the lower carriage; *D*, upper carriage; *F*, feed-screw; *G*, feed-screw stand; *M*, ratchet-lever; *K*, ratchet-wheel; *L*, crank; *W*, clip; *Q*, diamond-post; *S*, wheel to raise and lower the diamond.

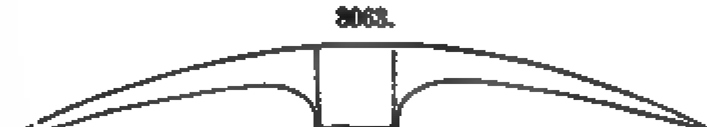
3062.

Fig. 3062 represents a combined furrow-dressing, cracking, and facing machine, so constructed as to take a millstone out of wind and keep it in face. The base-plate consists of a ring turned perfectly true, which rests on the face of the burr, extending nearly around its whole circumference. The device for furrow-dressing, cracking, and facing is fitted to this ring base-plate rigidly, and yet is adjustable, and the diamond cutter is made to work true with the face of this base-plate. The extended bearing this base-plate has on the face of the burr prevents the machine from being affected by any local elevations or depressions in the millstone, and hence the action of the machine brings the stone to a true level or face.

MINE APPLIANCES. (See also ROCK-DRILLS, and BLASTING.)

Mining Picks.—There are three principal types of picks in use among the miners of the Pacific slope: the "surface-pick," or ordinary excavating pick, Fig. 3063; the drifting or quartz pick, Fig. 3064; and the poll-pick, Fig. 3065. There is also a coal-pick. There are two forms of surface-pick, the round-eye and the flat-eye. The first weighs from 4 to 7 lbs.: the 5-lb. pick, which is about 27 in. in length, being that commonly employed. The round-eyed pick is generally used in surface or placer mining, and is probably the most convenient tool for that work. The flat-eyed pick is preferred for sluicing, as it does not spatter the water so much as the round-eyed. The heavier picks of these styles are used chiefly in grading and heavy digging in bed-rock.

3063.



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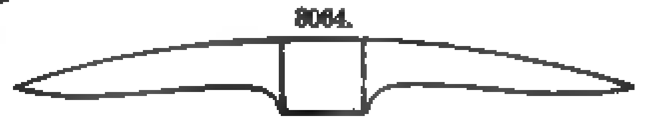

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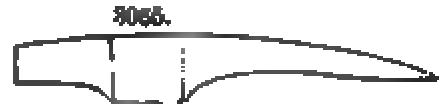
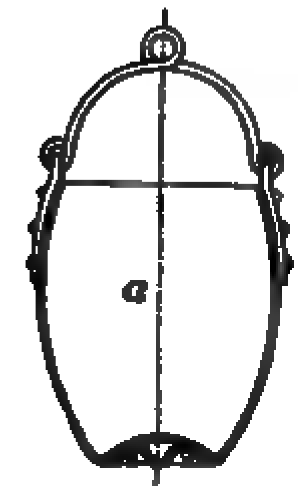


The medium-sized quartz-pick is 24 in. long, and its weight is from 3½ to 6 lbs. The small sizes are used chiefly in contracted narrow drifts, where there is not much room to swing the tools, and also in working out the gouge or selvage from quartz veins. The larger sizes are mostly used in drifts where there is plenty of room, and in pulling down rock. The "poll-pick" is a favorite form with miners, since it combines the long, sharp point for drifting and a hammer-head for striking and breaking the rock or driving gads. It is a pick and hammer combined. The medium size, weighing 5 lbs., and about 16½ in. long, is most in use; but the weight varies from 4 to 7 lbs., some miners preferring the largest size. Such picks are made stout and strong. The hammer end or head in the medium size is 3½ in. long and the point about 10 in., the eye being 3 by 1 in. These various styles of picks are made of the best quality of iron and steel. The handles are made of white hickory, and usually 36 in. long for the surface picks and 34 in. for the drifting and poll picks.

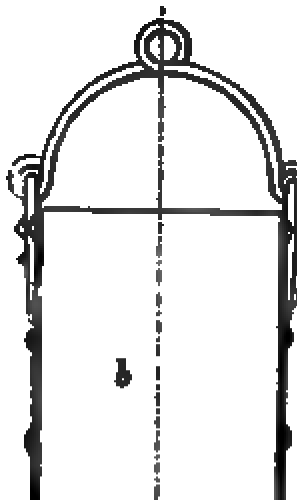
Kibbles and Buckets.—When a suitable location has been selected for sinking a shaft, either for prospecting or for developing a gold or silver ore body, the extent of which is already known, and ground has been broken, the rock and materials are brought to the surface in a Cornish kibble, shown in Fig. 3066, which is also used to lower and raise the miners to and from their work. It is the simplest form of mining bucket adopted, and, while giving satisfaction to those operating through a vertical shaft, is especially designed to follow the irregular inclination of the vein after it has been penetrated by the vertical shaft in the ordinary process of sinking, and before developments have progressed far enough to warrant the introduction of more complete and expensive appliances. Where the shaft is vertical continuously, a rock-bucket, Fig. 3067, is used. To diminish the wear and to assist in passing obstructions, heavy bands, sometimes of steel, are put around them. Both the kibble and rock-bucket are made of boiler-plate iron with a heavy bail at top and ring at bottom, to facilitate handling and discharging.

Where it is desirable to save time and power in operating through shafts of various inclinations,

3066



3067.



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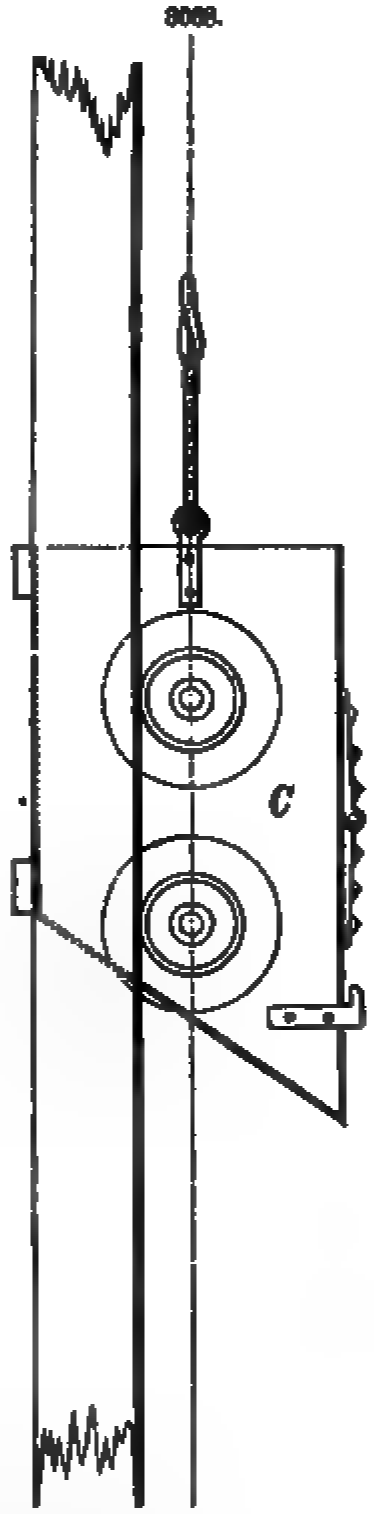


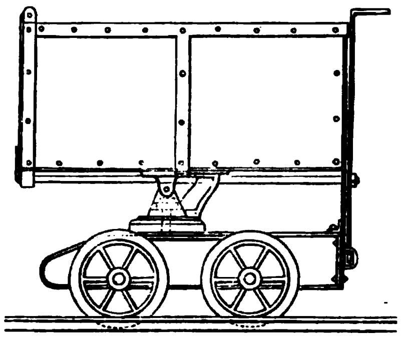
3069.

a skip of the design shown in Fig. 3068 is frequently selected. It is fitted with wheels to run on guides and a door for discharging.

Safety-Cage.—Fig. 3069 shows the style of safety-cage most generally adopted. *a a* are safety-catches, which are held in position by the weight of the cage, but released and forced into the wooden guides by heavy steel springs the instant connection between the rope and cage is broken. *B* is the hood to protect the miners from small particles of rock and ore that may accidentally fall into the shaft. *C* is the car and *E* the rope. A second cage *D* is frequently attached to the first, as shown, making what is known as a "double-decker;" and sometimes a third is added, making a "triple-decker." Fig. 3070 shows a swivel dump-car which is commonly used in connection with the safety-cages for removing, at a single handling, the ore from drift or slope in the various levels of a mine directly to the ore-bin of the quartz-mill. When water is struck, it is removed from time to time by a water-bucket, which is attached temporarily to the same rope through which the hoisting of materials is effected. For a light flow of water the bucket shown in Fig. 3071 has been found to be

very serviceable. *A* is the bucket and *B* the valve, which is forced open by the upward pressure of the water when the bucket is lowered into the sump, and raised by the handle for discharging when the surface has been reached. As soon as the flow of water becomes strong enough to interfere with the progress of sinking, a much larger, stronger, and more effective bucket or tank is introduced. In the tank shown in Fig. 3072 the inlet-valve *C* at the bottom opens and closes automatically, while the discharge-valve *D* on the side is controlled by a rope or chain passing over a pulley at the top. Later in the developments of the mine this bucket can be used to keep down the water

3070.



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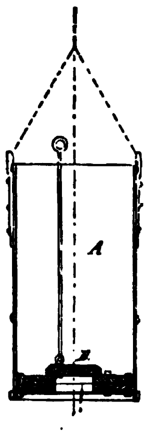

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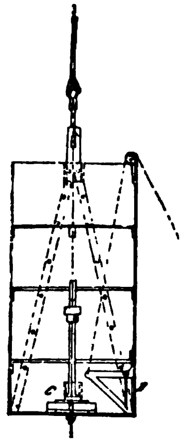


while the pit-work is being put in place in the pumping compartment of the shaft, or while repairs to the same are being conducted. To accomplish this without decreasing materially the out-put of ore, the water-bucket is sometimes attached to the bottom of a safety-cage, as shown in Fig. 3073, which gives the disposition when operating through a shaft slightly inclined.

To facilitate operations in sinking vertical shafts to great depths through rock where the location and extent of the vein are known and large quantities are to be raised, the Requa self-dumping skeet, Fig. 3074, was designed. As the skeet reaches the surface, the latches on either side are raised automatically; the wheels, shown at one side, are forced to pass between incline-guides, and the skeet is tipped sufficiently to discharge into a chute leading to the rock-dump. As it begins its descent, the wheels force it back into position, the latches fall, and the skeet is quickly dropped to the bottom to be reloaded.

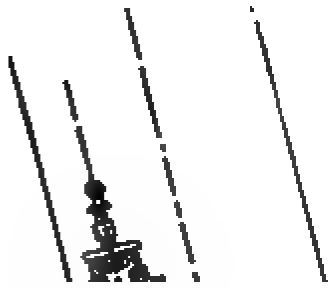
Safety-hooks for detaching the rope from safety-cage, rock-bucket, water-bucket, or skeet, when, through carelessness or accident, they are carried in their ascent apart from the landing at the surface, and toward the sheave set in the gallows-frame overhead, are shown in Figs. 3075 to 3079. The principle upon which they operate is essentially the same. If in passing through a ring set in the gallows-frame the connection between bucket or cage and rope is broken, the latter passes on to the reel of the hoisting engine, while the former is held where it stopped by the safety-catches.

Mining Hoists.—The mechanical devices that have been resorted to for raising ore from mines to the surface are as numerous as the conditions they are designed to satisfy; but by grouping together those that possess the same general features, they can all be referred to a few special types.

An expert, who is called upon to decide what class of hoisting machinery is best adapted to the wants of any particular mining community, at the outset will provide himself with an inexpensive prospecting apparatus that will enable him, by the usual methods of sinking and drifting, to institute a series of underground explorations to determine the width and extent of the vein, as also the character and value of the ore. Possessed of these facts, he will adopt such a practice as the developments would seem to warrant. If permanent works are decided upon, the special type of hoist selected is modified in detail according to the depth and size of the ore-body and other local requirements. When ground is first broken for sinking, a common windlass is generally set over the shaft, and the kibble or rock-bucket raised or lowered by one or more men. If horse-power is preferred, the hemp or wire rope, as it emerges from the shaft, is carried on to the sheave, set in a strong gallows-frame directly overhead, and thence around a vertical drum operated by one or more horses. In the *horse-whim*, Fig. 3080, *A* is the drum, *B* the rope, which is attached at the lower end to the kibble or bucket, and *C* the point where the power of the horse is applied.

When a depth of 200 or 300 ft. has been reached, man and horse power are abandoned and steam substituted. According to the developments, a selection is now made, from a great variety of hoists, of one that is best suited to satisfy all the demands likely to be made upon it. If, as is the case on the Comstock lode in Nevada, the location and extent of the vein have been fairly determined already, and the depth to which exploitations will be carried has been decided upon, permanent hoisting works are immediately erected. If, however, as is more common, nothing of sufficient value to warrant the introduction of heavy and expensive machinery has been revealed, the simplest form of hoist is adopted. It may consist of a vertical link-motion engine, connected to a drum for round rope by a set of intermediate gears, as shown in Fig. 3081. Here *A* is the engine, *B* the drum, *F* the fly-wheel, and *P* the foot-lever. Where fuel is expensive and economy is sought, high-pressure

3073.



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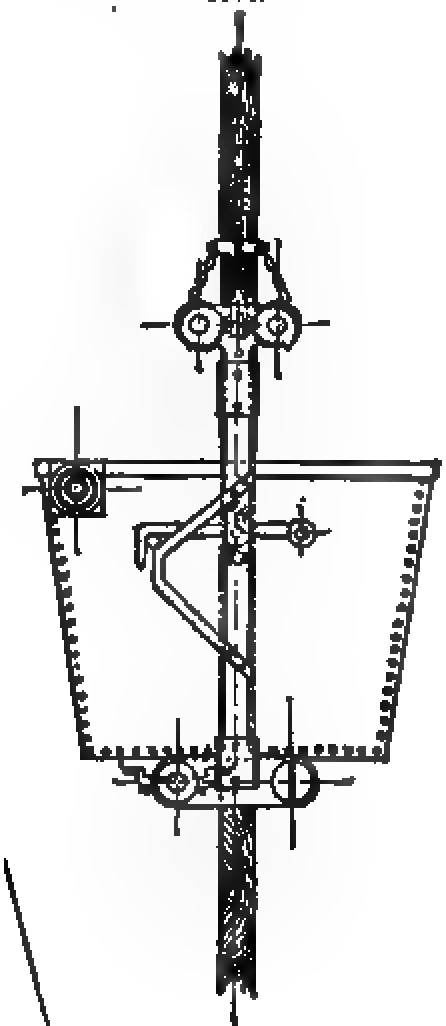

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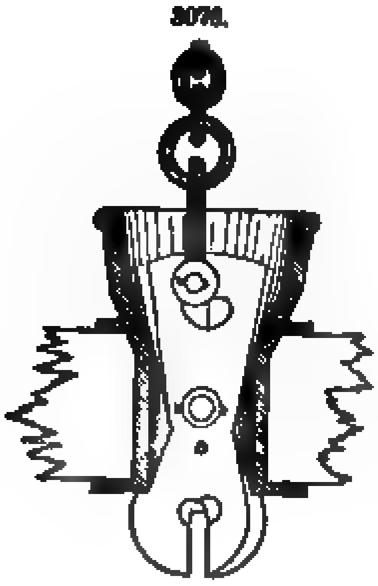
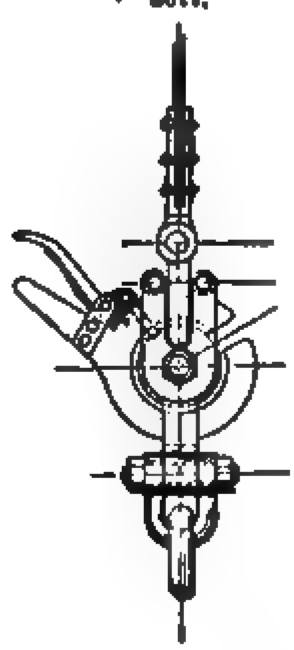


3077.



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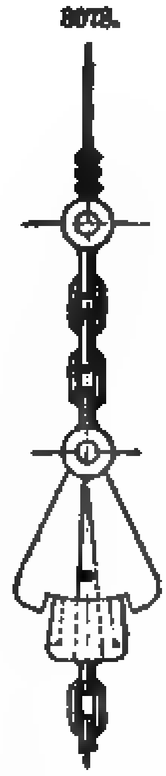
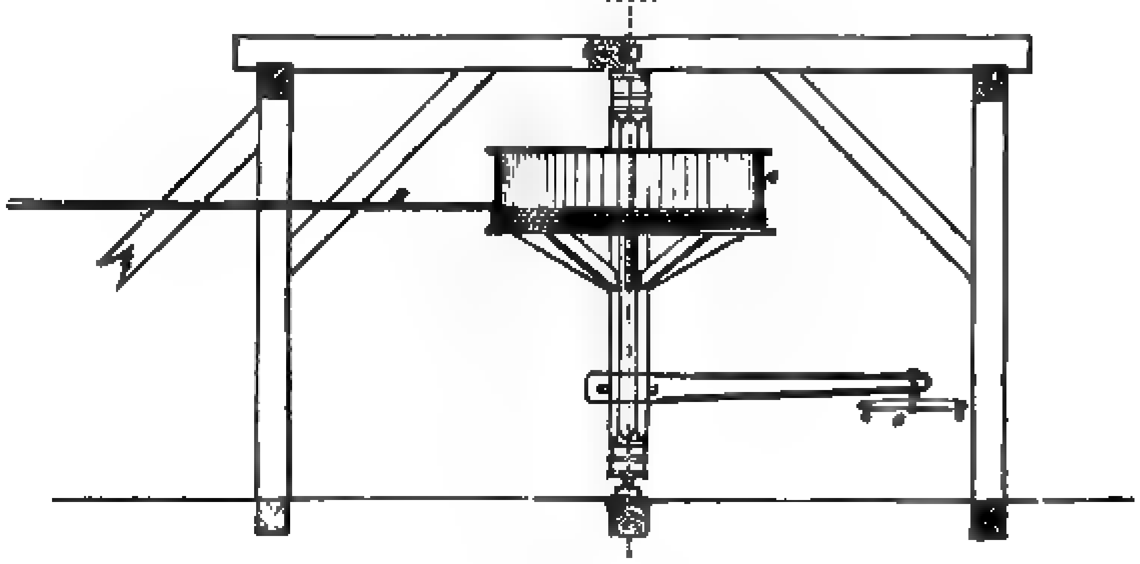


3079.

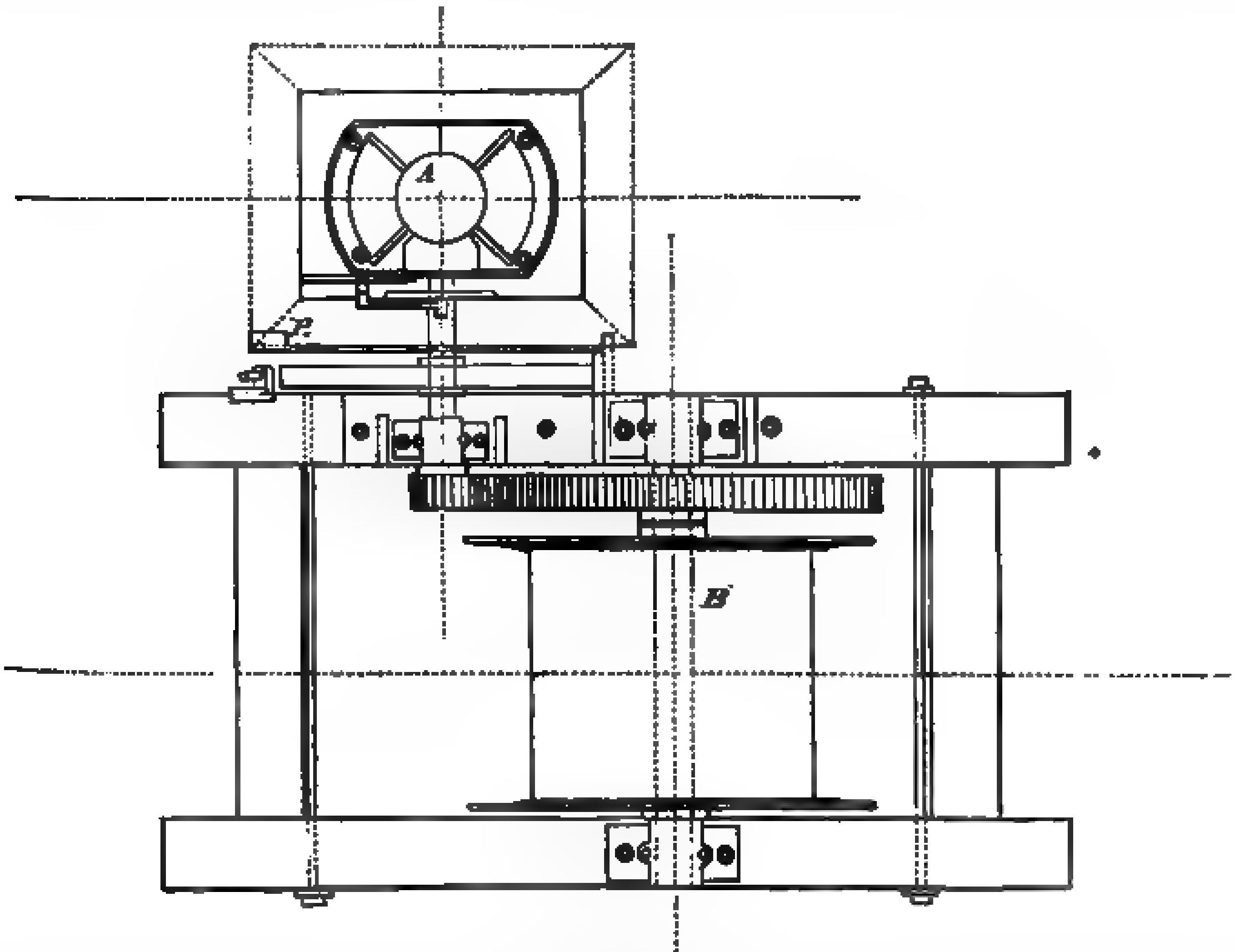
3080.



steam is used, and advantage is taken of its expansive properties by a suitable cut-off. A much higher duty is secured by following the modern practice of working two engines, with their cranks set at right angles, through one crank-shaft. For light loads and depths not to exceed 600 ft., the friction-geared hoist has grown into considerable favor at the East, but much less so at the West.

For a single compartment the disposition shown in Fig. 3082 has proved most satisfactory. *A A*

3081.



are the engines, *B* the drum, *C* the friction-pinion, *D* the wheel, *E* the brake-ring, and *F F* the sliding boxes. It will be noted that the friction-wheel is cast with the drum and brake-ring, and is forced squarely forward to gear with the pinion, by a series of levers operating with equal force upon both sliding boxes. Through a system of hand and foot levers, the machinery is brought under the complete and easy control of the engineer, who lowers the bucket with the brake, while the engines are at rest. By increasing the power of the engines and adding more drums, a number of pits or shafts, located some distance apart, can be operated quite economically. By means of a governor the engine may be controlled automatically, and, while running continuously, adjust the cut-off to suit the load.

3083.

In new districts, where it is necessary to do considerable prospecting before any definite knowledge of the ore-deposit can be obtained, a boiler of the locomotive type is attached to the same frames as the engines, and the whole made as light and compact as possible for moving rapidly from place to place. Such is the semi-portable hoist shown in Fig. 3083. *A* is the boiler, *N N* the engine-cylinders, *C* the crank-shaft common to both, and *D D* the drums. A pin *E* in the gear-wheel admits of connection to pumps if necessary. The drums are not keyed on to the shaft, but are brought into action by their respective clutches, which slide on feather-keys, and can thus be used separately or together as desired. The brakes are set by levers placed convenient to the engineer.

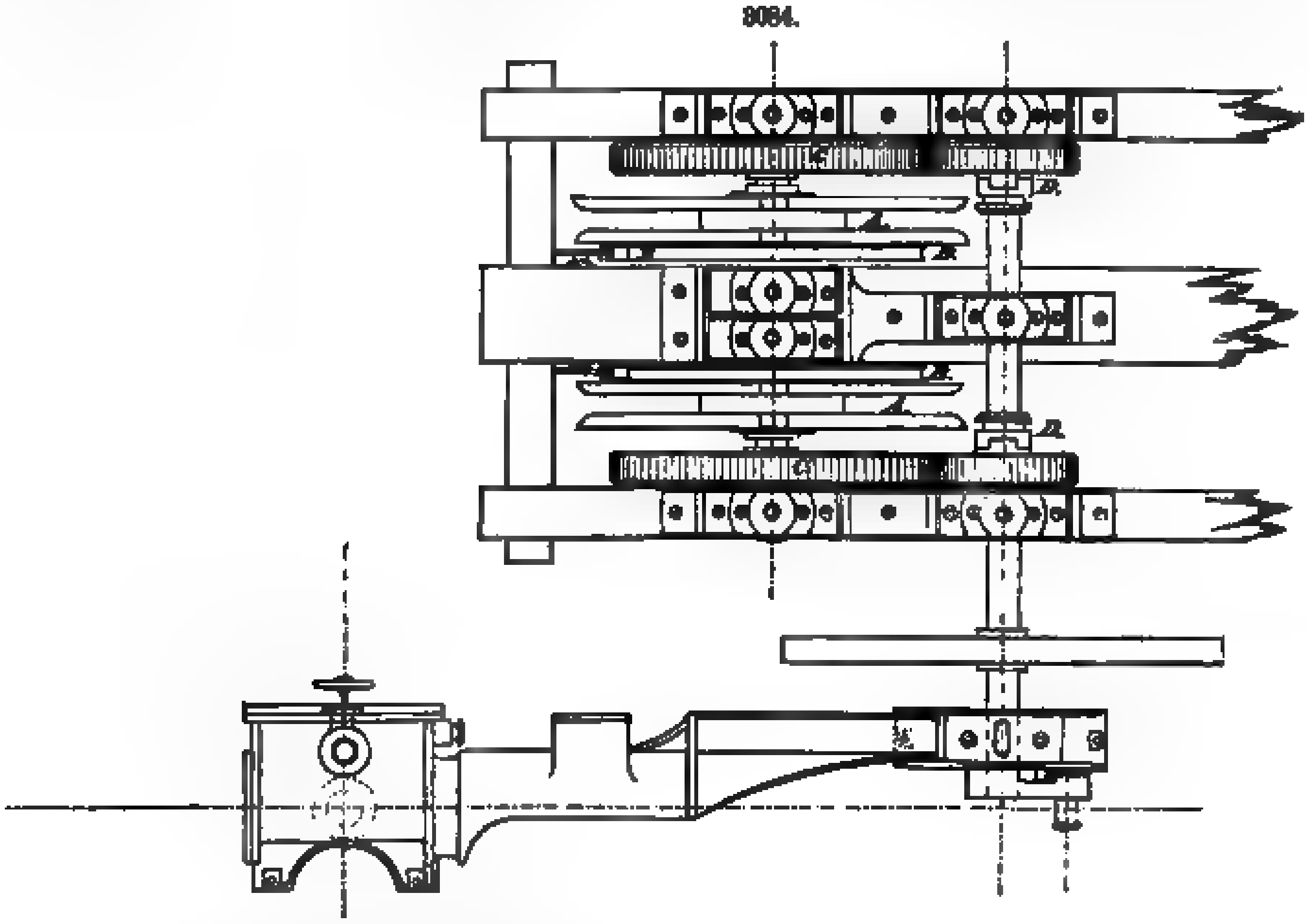
By the use of separate buckets in a two-compartment shaft, or better still by the introduction of safety-cages, a much more economical system is secured. If this latter is effected, the ore can be

loaded directly into the car at the end of a drift, run to the shaft, placed upon the cage, hoisted to the surface, and dumped, all at one operation. With either buckets or cages, the best results are obtained by winding the ropes on the drums in opposite directions, the one over and the other under, whereby the weight of the light descending cage is utilized in raising the loaded one that is ascending in the other compartment. Where the workings have attained a greater depth than 800 or 1,000 ft., and the ropes and attachments are increased materially in weight, larger engines are brought into requisition.

3063.

When this point has been reached, the further use of a round rope is fraught with so many difficulties, that it has been almost entirely abandoned in this country. The objections urged against it can be summed up briefly as follows: 1. A round wire rope, in winding upon itself, is rapidly destroyed by chafing. To avoid this, drums of a face sufficiently wide to coil from 1,000 to 4,000 ft. must be employed, and regular grooves turned spirally for the reception of the rope. 2. In winding upon a drum of small diameter, the strains upon the individual strands are so irregular that they soon give way. To overcome this, drums of a large diameter must be designed. 3. In passing from the overhead sheaves down the shaft, each rope must occupy a central position in its own compartment. This allows no lateral motion to the sheave, and forces the rope to leave and wind upon the drum at an angle that is continually increasing the instant the middle of the drum is passed, and a tendency on the part of the rope is created to leave its groove, climb the incline that separates the respective layers, and chafe and wear away. 4. In case the former objection is removed by erecting the drum at a considerable distance from the mouth of the shaft, and thereby decreasing the angle referred to, a new one arises in the increased sag and sway of the rope between sheave and drum. This introduces irregular strains, and prevents the engineer from landing his cages or

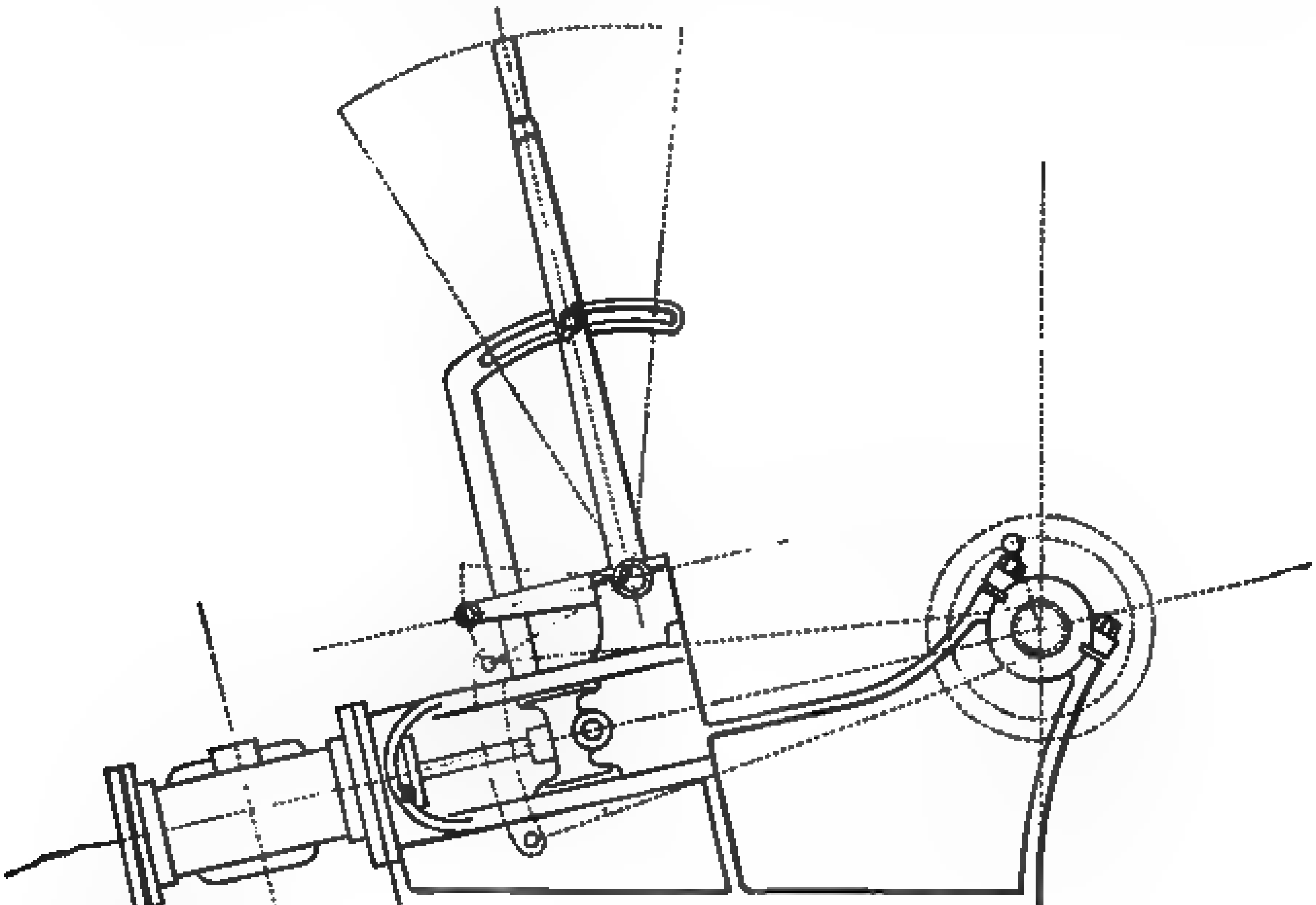
3064.



giraffes with the accuracy necessary for rapid working. 5. In districts where the surface of the country is very much broken, or where for various reasons but a limited space can be reserved directly about the shaft, a serious objection to the round-rope plant arises on account of its size. 6. The round rope cannot be removed from its drum, cleaned, and repaired with the same facility that a flat rope can.

There are at present (1879) but three instances where round ropes are in use in this country for hoisting from very deep levels. At the time they were introduced, flat ropes were looked upon with suspicion, as they had not then been tested for any great depth. Coupled with this was the fact that, for a given length and an equal load, the round rope was discovered by experiment to be the lightest, which is readily explained by the difference in their mode of construction, the strands being carefully wound together in the round rope, while in the flat rope they are simply placed parallel and secured to each other by cross-wires. This matter of the amount of dead weight hanging in the shaft was considered a very important one. In two of the three cases noted, the vertical shafts had penetrated to the foot-wall of the vein, and as the safety-cages could not follow down the incline, the present plants were designed to operate a single giraffe each from the bottom of the incline to the foot of the vertical shaft, where its load could be transferred to the safety-cages. To accomplish

3086.



this without affecting the previous hoisting arrangements, the new round rope, carrying the giraffe at its lower end, was hung in one corner of the pump compartment. This experience has developed a practice in America which is widely different from that adopted in England and on the continent of Europe, where round rope is in great favor.

In following out the practice of preferring flat ropes, geared engines, as shown in Fig. 3084, were

first used. As will be noted, the loose pinions on the engine-shaft are brought into action by their respective clutches, allowing the reels to be used separately or together. The practice of balancing the cages by winding the ropes upon the reels in opposite directions has been pretty generally adopted with this type, and with most economical and satisfactory results. In the figure, *A A* are reels for flat wire rope; *B B*, brake-wheels; *C C*, spur-wheels; *D D*, clutches; and *E E*, brake-straps, by which the motion of the engine can be regulated at will, or the cages lowered independently of the engine. While this style of hoist has done good service in the past, and will no doubt prove satisfactory in the future under certain conditions, the fact that speed is sacrificed to power by the intermediate gearing would not recommend it for rapid or extensive workings.

When large ore-bodies have been discovered at depths ranging from 1,000 to 4,000 ft. from the surface, and it becomes necessary to remove them with the greatest expedition, the direct-acting hoist, Fig. 3085, is employed. In this design, the heavy gearing of the previous type and the friction arising therefrom are avoided. The reels are placed upon the engine-shaft, and brought into action by clutches sliding on the same and operated by clutch-levers. The practice of working the cages together and balanced, by winding the ropes upon the reels in opposite directions, is followed out. A single engineer and brakeman control all the movements of the cages, the engineer landing the ascending one and the brakeman the descending one continually. The greatest leverage is secured at the moment of starting the load by winding the rope on the empty reel, and this decreases with the dead weight as the rope winds upon itself. In deep mining this dead load will vary from 3,000 to 7,000 lbs., according to circumstances. The cages sometimes attain a speed of from 4,000 to 5,000 vertical feet per minute. In the figure, *A* is the reversing lever; *B*, the throttle-lever; *C C*, the clutch-levers; *D D*, dials carrying pointers driven from the engine-shaft to indicate the exact position of the cages in the hoisting shaft at every part of the run. As far as our experience goes, this type of hoist combines the greatest power with the most rapid and economical working, over 1,200 tons of ore having been taken out through a two-compartment shaft in 24 hours by a single hoist.

When it becomes necessary to sink a small shaft or winze from a point in a drift, the rock is raised to the level of the drift by a small engine known as the baby-hoist. Fig. 3086 represents a style of engine most generally used for this purpose, having two cylinders working through the same crank-shaft. The engine is made to take up as little room as possible, so that it may be placed on a car and dropped down the shaft, or moved from one part of the mine to another. F. H. McD.

MINING. Mines are excavations made in the earth for the extraction of minerals. When the material to be extracted is a rock of any kind, the excavation is known as a quarry. See in this connection the following articles: AIR-COMPRESSORS, BLASTING, BLOWERS, BREAKER OR CRUSHER, EXCAVATING MACHINERY, EXPLOSIVES, FUSES, LAMPS, PUMPS, QUARRYING MACHINE, ROCK-DRILLS, TUNNELING, and WELL-BORING.

Access to mineral deposits for permanent exploitation is established, first, by suitable wagon or tram roads on the surface, and secondly, by either stripping the overlying rock and soil from the deposit itself, as is done in quarries, clay-banks, and some iron mines, or by sinking a shaft or running a drift or cross-cut from the surface into the deposit. In the case of beds or veins which dip at a convenient and uniform angle, the shaft may be carried down upon the deposit itself, and is then usually called a slope or an incline. For less regular deposits, and for those in which the angle of inclination is inconvenient or variable, or the vein-matter is too valuable to permit the leaving of it in pillars to protect the shaft, it is better to drive a vertical shaft at some distance from the outcrop, in the hanging wall, so as to strike the vein at a considerable depth. A gallery run from the surface in a nearly horizontal line, to effect access and drainage, is called an adit, or entry; and in some situations, as at the base of steep hills, this may be made the principal feature at the mine, the main workings being carried on through it until the vein is exhausted above its level. Sometimes the nature of the shafts permits the opening of mines at different levels by means of adits.

SHAFTS.—Sinking shafts in sound rock is commonly performed in this country by the ordinary operations of drilling, blasting, and quarrying. Shafts are usually laid off in three, sometimes in four compartments, for systematic operations with the most approved appliances. The largest compartment is given up to the pit-work of the pumps; the others are fitted with guides which extend throughout the whole length of the shaft, and hold the safety-cages in position as they ascend and descend. The shape of the shaft is maintained by timbering and planking, as shown in Fig. 3087, in which *A* is the pump-shaft, *B B* the hoisting shafts through which the safety-cages move, and *C* is the hoisting shaft through which the incline is reached and operated. *D* represents timbers 14 in. square, framed together and placed 6 ft. apart from centre to centre throughout the entire length of the shaft. *E* is the lining of 4-in. plank, *F F* is the filling, and *g g* are the guides for the cages.

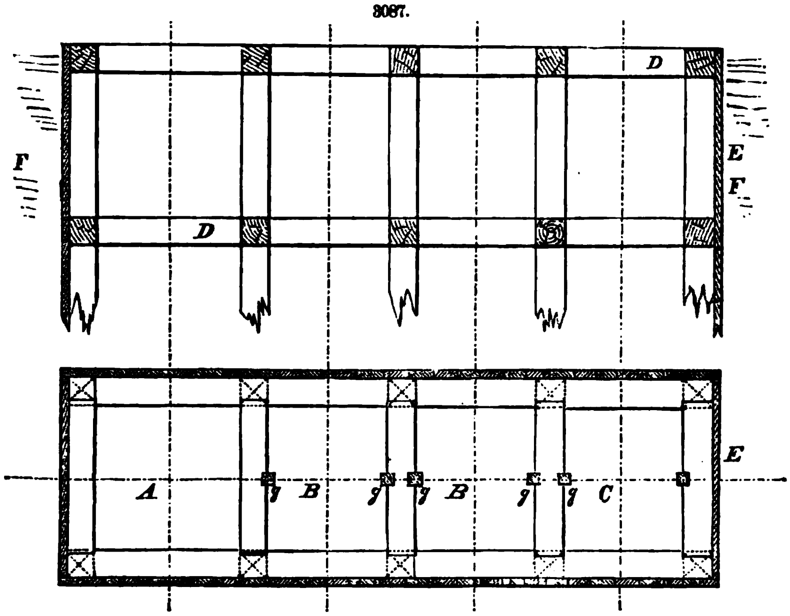
Boring Shafts.—In France and Belgium important advances have been made in boring shafts by the aid of tools of immense size, weight, and strength, actuated by steam-power. The most striking feature of this system, next to boring, is that the work is executed and the shaft is lined without pumping the water out of the excavation. The sinking proceeds under water, and the shaft is not drained or entered by miners until it is completed and lined from top to bottom.

The Kind-Chaudron Process is one of the latest and most improved systems of shaft-boring. The principal tools used are the following: The *trepans*, the object of which is to disintegrate the rock by concussion. These are attached to the extremity of a series of wooden rods with iron armatures and screw ends, fastened to the extremity of a balance or striking beam, put into motion by means of a single-acting or bull engine worked by hand. Sand buckets, which are large plate-iron cylinders with valve-bottoms and handles, which allow of the dumping of their contents, are used to dredge the dirt and slush from the bottom of the shaft as the work progresses. Shafts are bored by the Chaudron process in two and occasionally in three successive operations. The first bore is made by the small trepan, generally about 4½ ft. in diameter, through which the detritus is extracted until the final completion of the shaft. This first bore is then widened by the use of the large trepan. The

apparatus employed in case of accidents or of special emergencies comprises a safety-hook, a grappling forceps of very ingenious construction, and the *fanchere* (fangsheer) or holding nippers. The small trepan is formed of two distinct portions—the blade and its stem. The first is made of a solid block of forged iron, into the lower portion of which are inserted a number of steel or of chilled teeth of a wedge-like shape, held in place by conical keys. The stem is attached to the blade by another set of strong keys, and to the suspension appliances by means of a sliding box. This last is a very important part of the apparatus, as without it the violent vibrations transmitted by the concussions of the trepan on hard rock would inevitably rupture the connecting-rods at every blow. The weight of the small trepan varies according to the work to be done; that exhibited at the Centennial Exhibition in Philadelphia weighed 15 tons. In trepans at first constructed by M. Kind the upper portion of the central stem was threaded to receive a screw which united to the slide; but this arrangement gave much trouble and soon got out of repair, and has subsequently been replaced by an adaptation consisting of two plates keyed permanently to the stem, replacing the male portion of the older model. The large trepan, employed for widening the bore made by the small trepan, consists also of a ponderous forged iron blade, carrying teeth at its two extremities, and a V-shaped guide, of the diameter of the small bore, situated in the central or toothless portion. The blade is united to the central stem by three arms strongly keyed. The weight of this tool as made at present is about 25 tons.

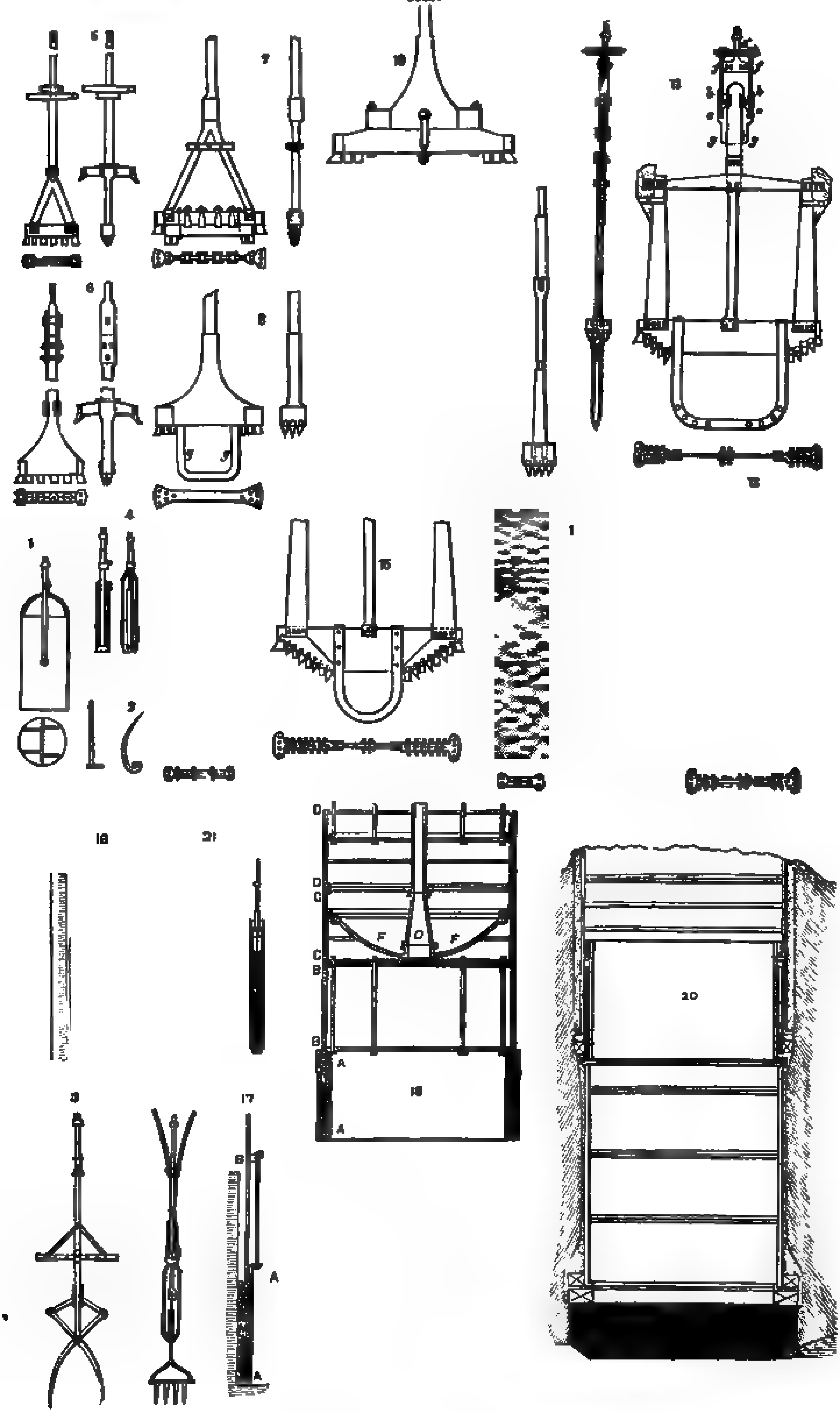
The whole apparatus employed in sinking and tubing a mining shaft by the Chaudron process is operated by means of two engines, the one destined to raise the trepans during the act of striking, the second to work a capstan which is used in lifting and lowering the various tools and the tubing.

3087.



We refer practical engineers for minuter details to M. Chaudron's able papers entitled "Foncage des Puits à Niveau plein," published in the "Annals of Public Works" of Belgium, and limit ourselves to the reproduction of drawings of the apparatus used, in Fig. 3088. No. 1, sand-bucket or dredging apparatus. No. 2, safety-hook for lifting the trepans and their connecting-rods in case of rupture of these last. No. 3, grappling-hook for extracting blocks of rock, detached teeth from the trepans, etc., from the bottom of the shaft. No. 4, fanchere, replacing the safety-hook in the event of a rupture of the main stem, or of that of one of the rods below the prominent collar at its head. No. 5, small trepan used at L'Hôpital for the first bore of 1.37 metre diameter. No. 6, small massive trepan for the same purpose, but in hard rock. No. 7, widening-trepan with a double blade, used in the air-shaft for a diameter of 2¼ metres. No. 8, large trepan for hard ground. *g g*, central guide occupying the bore previously made by the smaller tool, and maintaining the apparatus in a central position. No. 9, large trepan for boring diameters of from 4.10 to 4.25 metres. No. 10, large trepan, made by adding a blade to trepan No. 7. No. 11, new form of trepan proposed by M. Kind for diameters of 0.70 to 1 metre through hard rock. No. 12, trepan for a first widening of the shaft to 2¼ metres in diameter. No. 13, large trepan for shafts of 4.20 metres diameter, with teeth arranged on an incline so as to direct the débris of rock to the centre. No. 14, small trepan for bores of 1¼ metre in soft ground. No. 15, large trepan for widening the above in soft ground. No. 16, kibble for receiving débris, proposed to be suspended in the shaft during the work of widening. No. 17, vertical section of the moss-box as fitted to the tubing of shaft No. 2 of L'Hôpital. *A A*, internal cylinder, carrying a flange at the bottom, forming the wall of the moss-box. This cylinder is suspended by means of six screw-bolts, which allow of its gliding on them as guides during

3082.



compression. *B*, first section of the tubing, which carries an outer flange and forms the other wall of the moss-box. *S S*, sheet-iron segments, which press on the moss and prevent exclusive vertical compression of the same. *M*, moss contained in the joint before compression. No. 18, assemblage of the parts which constitute the lower end of the tubing. This portion alone is lowered to the surface of the water before the series of rings of the tubing are adapted successively to it. *A A*, internal wall of the moss-box. *B B*, first section of the tubing, forming the outer wall of the moss-box. *C C*, second section of the tubing, which carries the false bottom and eventually floats the whole column. *D D*, third section of tubing, with the suspension flanges which attach to the guide-rods for the maintenance in a vertical position while sinking. *F F*, central pipe, adapted by its lower end to the false bottom, and which is carried to the top in successive lengths along with the outer tubing; water being allowed to penetrate by means of suitable cocks inserted at various heights in this tube, permits of the gradual and simultaneous lowering of the whole casing independent of its weight. When this has reached the bottom, and the moss-box has closed by compression, the water is pumped out of the shaft, and the false bottom and central tube extracted, after which the permanent foundations are established. Before, however, the water is taken out of the shaft, a coating of concrete is introduced between the tubing and the outer walls of the shaft, and permitted to harden there. The shaft is now found to be perfectly tight in all its parts, if the work has been properly conducted. No. 19, foundation for the tubing as established at L'Hôpital. No. 20, the same for the shaft of Sainte-Barbe. No. 21, special ladle for the introduction of the concrete. This tool is furnished with a movable bottom, connected to a piston-rod in such a way that pressure on the latter causes the evacuation of the contents.

The expense of sinking shafts by this system is always lower than by the ordinary method of mining in all cases where the use of at least two pumps of a diameter of 0.55 metre would be needed in the latter case, but it varies according to the nature. The duration of the operation is considerably prolonged whenever the soil is of a very crumbling or running nature, or in cases where it is exceptionally hard and tenacious. Under the best conditions the cost of sinking and tubing a shaft by the Chaudron process may be set down as about $500 per metre on an average for a diameter of 12 ft., and has never in the worst cases exceeded about $800 as a maximum. For a width of 15 ft. we may safely estimate on a minimum cost of $800 per metre, and not to exceed $1,200 as a maximum. The occurrence of shifting sand or gravel, or of loose clay or quicksand, is always a cause of supplementary expenditure, as it may render the use of a certain amount of protective or temple tubing indispensable.*

Adits are placed with reference to securing the greatest depth below the surface by running as short a distance as possible, particularly in barren rock; with reference to the presence of a good place for a "dump" at the adit mouth; and also with reference to easy escape of water, freedom from flooding by freshets, and facility of natural ventilation when the adit is to be connected with a shaft. For the latter purpose it is well that the adit mouth should not be in a narrow ravine or in the corner of a valley. Dimensions of adits depend upon the amount of water expected to run in them and the other purposes to which they are to be put. When in barren rock, it is an object to make them as small as practicable; 7 ft. high and 5 to 6 ft. wide is a convenient size. But when transportation is to be carried on and double tracks are to be laid, the dimensions must be increased. The height of the adit available for passage is diminished by the water-channel, which usually runs under the floor or in a ditch at one side. The grade of adits is determined with reference to the amount and character of the water flowing in them and the speed which it is desirable to give to the current. The ancient mining regulations of Prussia required of deep adits a grade of from 1 in 800 to 1 in 400. Some of the adits at the coal-mines of Saarbrück rise at the rate of 1 in 1,600; others at the rate of 89 in 64,000. According to the Saxon law, the grade may vary between 3 in 10,000 and 1 in 1,000. The long Ernst-August adit in the Hartz has, for a length of nine miles, an average grade of 0.67 in 1,000. Here the water in the adit is itself used for transportation, and the current is intentionally kept slow. Access is further obtained to the different parts of the mineral deposit by subordinate shafts and galleries, excavated in the deposit. These interior shafts not extending to the surface are known as winzes, and usually serve to connect the galleries on different levels. The galleries are known as levels or drifts in vein-mining, and gangways in coal-mining. When a mine is opened by a vertical shaft, the vein is sometimes cut by a cross-cut level run from the shaft through barren rock, at a point higher than the intersection of the shaft and the vein. From the point where the cross-cut enters the vein, levels are then run in both directions horizontally on the vein. After the main shaft has reached the vein and has been carried through it, the distance between vein and shaft of course grows larger with increasing depth, and the vein must be again opened by cross-cuts from the shaft at different levels. The levels opened in the vein are so many parallel roads on the vein, succeeding each other every 60 to 100 ft. in depth. The winzes connecting them serve both in ventilation and in extraction, besides affording convenient access to different parts of the mine. The running of drifts to make connection with old and abandoned workings is sometimes dangerous, when the old workings are full of water and their exact position is not known by surveys. In such a case the approach is made cautiously, and a bore-hole is kept in advance, to tap the accumulated waters in such a way as to avoid an excessive flow, or give the workmen time to escape. An accident of this kind at the Gouley mine, near Aix-la-Chapelle, in 1835, which caused the drowning of 63 miners, gave rise to the publication by the government of the Rhenish province of exact regulations, which constitute an excellent guide to the mining engineer.

Extraction of Minerals.—To perform the work of regular extraction with due economy and safety, the following circumstances must be considered: the shape of the deposit, as a tabular or

* A paper read before the American Institute of Mining Engineers, at Philadelphia meeting, June, 1876, by Julien Deby, C. E.

sheet deposit, a mass or stockwork, regular or irregular, etc., and if a tabular deposit, like a fissure-vein or a bed, then its course and dip, its folds, basins, faults, and breaks; the thickness and inner structure of the deposit, or, in ore-veins, the nature and distribution of the ore-bodies, the amount of barren gangue, and in coal-beds and other deposits the proportion of marketable to waste material; the character of the "country" or wall rock, as making a solid or a precarious roof, and requiring more or less support; the number, relation, and distance apart of several deposits which it may be desirable to work at once or successively, as for instance seams of coal, lying one under the other; the conditions of ventilation, particularly where explosive gases are to be feared; the conditions of drainage; the character, abundance, and price of materials for underground supports (timber, masonry, iron pillars, loose rock, or earth); the size and shape of the pieces of material to be extracted (commercially important in coal and quarried stone); the method of excavation to be employed (picking, shoveling, fire-setting, hydraulic sluicing, leaking, blasting, etc.); and finally, in a subordinate degree, the nature of the mineral itself, as for instance very rich and brittle silver ore, which is liable to be lost in fine particles among the piles of waste, or some kinds of coal which deteriorate by standing too long in the mine after they have been exposed and drained, or clays which become like quicksands in contact with water. Any one of the foregoing conditions may, under certain circumstances, be decisive as to the choice of a method of extraction.

The subject of hydraulic mining is separately treated under MINING, HYDRAULIC. The other modes of extraction may be divided into two classes: those in which the space excavated is refilled wholly or partially with waste material, and those in which no such "packing" or "gobbing up" is employed. The former class is subdivided, according to the direction in which the work proceeds, into overhand stoping, underhand stoping, cross stoping, and long-wall working. (The latter method and its modifications, used chiefly in coal-mining, where the seams are not too thick, steep, or variable, may be employed either with or without gobbing up.) The word *stope* is probably a corruption of *step*, and refers to the stair-like appearance presented by the face of the excavation. Overhand stoping is conducted as follows: From the level below the ground to the exploited, a "raise" or upward shaft is driven up into the ground, and from this the different "breasts" are driven horizontally on the vein, in one or in both directions. The extraction begins at the bottom, by the excavation of a block having the width of the vein, a height of 4½ to 9 ft., and a length of not less than 7 nor more than 30 ft. In this work two sides of the rock are always free: the upright face, toward the central shaft, and the lower horizontal side, over the level. When the breast has been driven far enough, new workmen may begin with a second breast, while the former still continue to advance.

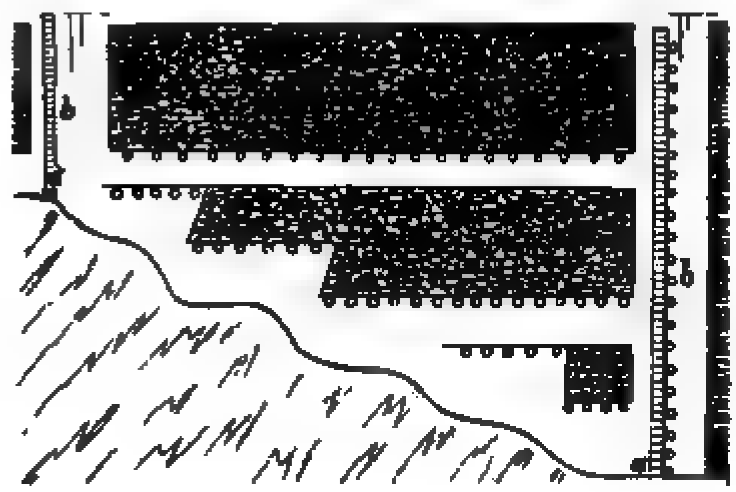
Fig. 3089, representing the profile of a double stope, shows the order in which the work proceeds. The space behind and below the workmen is filled up with the waste rock, broken from the vein in order to get at the ore, or with rock brought from elsewhere for this special purpose. Openings or "chutes" are left in this, through which the ore can be allowed to fall to the level below, where it is received in cars. This level is usually protected by a roof of stulls and lagging, on which the waste rock is piled, as is shown in Fig. 3090; or a portion of the vein is left standing over the level as a protection. The workmen stand on the waste rock, and stoping goes on in the manner indicated, until the whole of the valuable mineral between the bottom level and the one next above (say 60 to 100 ft., measured on the dip of the vein) has been extracted. Of course, by starting stopes at different points on the lower level, within the limits of the mining claim or the body of valuable ore, more men can be set at work. But the regular productiveness of a mine is not susceptible of indefinite increase in this way. The maximum rate of exploitation which can be maintained until the mine is entirely exhausted, depends upon the rate at which the shaft or shafts can be sunk and new levels opened at greater depths. The too rapid exhaustion of one level would necessitate a suspension of active extraction while the next level below was in course of preparation; and in this work of sinking shafts and running drifts (sometimes called the "dead work" of the mine) it is not possible to multiply the number of men so as to secure more rapid progress. Only so many men can be accommodated at the bottom of a shaft or the end of a drift; and when their effectiveness has been raised to the highest point by selecting good workmen, dividing them into three "shifts" or gangs, working eight hours each in turn, employing the most suitable tools and explosives, and, if circumstances are favorable, drills operated by steam or compressed air, the limit of practicable progress has been reached; and this determines the normal productiveness of the mine. Driving the stopes faster than the dead work is "robbing" the mine.

Underhand stoping is the reverse of the method just described. Here the stopes begin from the level above, and may be commenced (if the presence of water is not too troublesome) before any lower level has been opened. The ore has to be hoisted, and the waste rock has to be lifted by hand and packed on stulls behind the miner, as shown in Fig. 3091. This system permits an earlier beginning of extraction, and gives the workman a firm footing on the solid vein and an easier and safer direction of working (viz., downward instead of upward). Moreover, there is less chance of losing small pieces of rich ore, which in overhand stoping get into the waste rock under foot and cannot be recovered. But overhand stoping has two great advantages: first, the convenience of rolling and dropping rock and ore, instead of hoisting them; and second, the saving of timber, which in most mining districts soon becomes expensive. The great amount of timber used in an underhand stope is not merely lost; it may give rise by its decay to slides in the packing, or the necessity of expensive repairs to prevent them.

Both overhand and underhand stoping are variously modified, as for instance in their application to any thick vein in which cross-stoping is not desirable. In such cases, the vein is worked in successive layers or zones, parallel with the walls, each layer, beginning with that on the foot-wall, being stoped out by itself, as a separate vein; 12 ft. is usually as great a thickness as can be stoped at one time with safety or convenience. Cross-stoping is common in working thick veins. In this method, the vein material is removed in layers, not parallel with the walls, but extending from the foot to the

hanging wall; and in each layer the exploitation takes place by driving breasts across the vein, leaving pillars between them; supporting the roof of the breast, 6 to 12 ft. wide, with timbers until it has reached the hanging wall; then withdrawing the timbers and packing the excavation with waste rock; and then extracting the pillars and replacing them also with waste rock. A cross layer of the vein, 6 or 7 ft. in vertical height, having been thus removed and the space packed, the operation is repeated with the layer next above. Fig. 3092 shows this method by a vertical cross-section. It is

3091.



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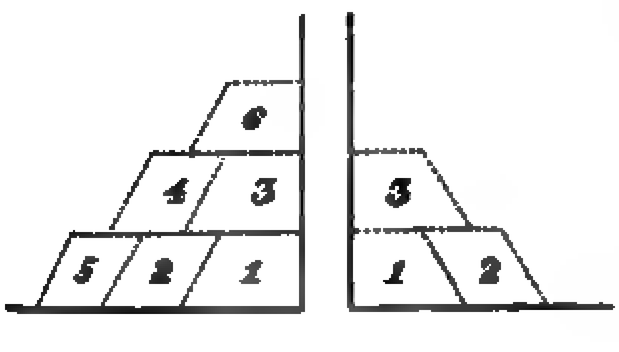

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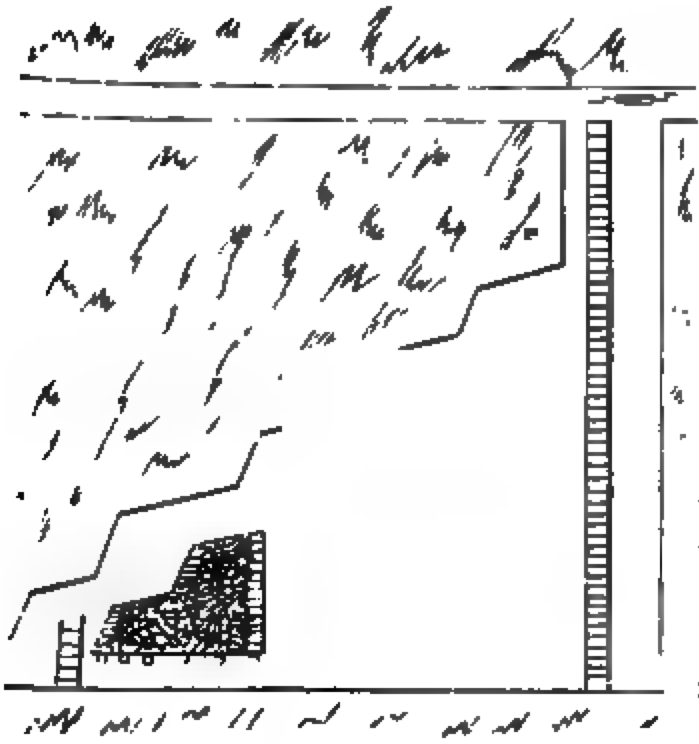

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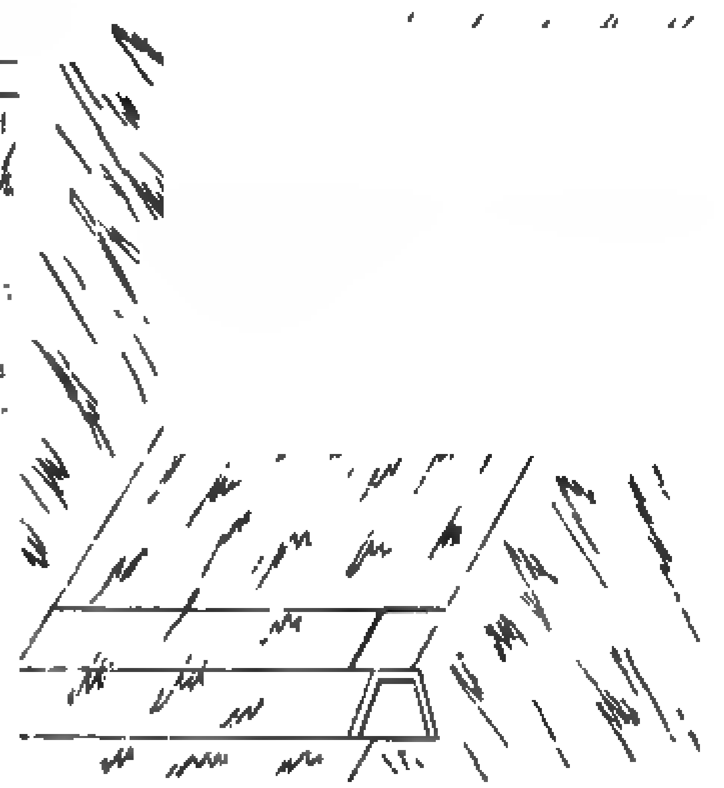

employed at the quicksilver mine of Idria, Carniola, and in various modifications at the zinc mines near Aix, the coal mines of Le Creuzot and St. Etienne in France, the mines of roofing slate near the Rhine, and the lignite mines in Lower Styria. Long-wall working is employed on nearly horizontal deposits, usually coal-beds. It may be classed as retreating or advancing, according to whether the extraction begins at the borders of the field or section of the bed to be worked, and retreats toward the main shaft and advances toward the limits. In the latter case roadways are kept through the ground already worked out. Varieties of this method are employed in the copper-schist beds of Mansfield, and at many foreign coal mines.

The methods of extraction without packing are: those in which the roof or hanging wall is supported by timbering, masonry, or pillars of the original material, left standing until the workings are to be abandoned; and those in which the roof is allowed to come down immediately after extraction. In the mines of the Comstock vein in Nevada, the spaces are kept open with elaborate timbering, framed as for immense houses. This is a great expense, besides being a source of loss and danger in case of fire. A conflagration in the Yellow Jacket, Kentuck, and Crown Point mines on that lode, which began April 7, 1869, not only cost many lives, but continued to burn, from 600 to 900 ft. underground, for many months, being sustained by the great quantity of dry timber in the stopes.

The system of extraction by breasts or chambers and pillars is practised chiefly in coal-mining. It is wasteful of coal, since the pillars of that material left standing are but partially recovered by "robbing," when the breasts are worked out. It is estimated that from 30 to 40 per cent. of the coal in the anthracite mines of Pennsylvania is thus lost.

PROTECTION OF THE WORKS AND WORKMEN.—Arrangements for the protection of the miners and works include timber or other supports, ventilation, and drainage. Shafts and permanent ways are carefully protected, if necessary, with stout timbering, masonry, or even cast-iron linings. Pillars of

rock left standing, piles of waste material packed in the empty spaces, and posts, stulls, lagging, etc., suffice for stopes. In some mines the temporary supports are iron columns, or even screw-jacks, which can be removed without damage and used again. Ventilation is necessary to remove explosive and inflammable gases (carburetted and sulphuretted hydrogen and carbonic oxide, which are also poisonous), and simply poisonous gases, such as sulphurous acid, carbonic acid, and quicksilver or arsenic vapors. Natural ventilation is secured by having two openings to the mine, at one of which (called the intake or downcast) fresh air enters, while the foul air escapes at the other (upcast). The difference in altitude between these openings, and the difference in temperature between the entering and escaping air, determine the strength of the natural ventilation. It is likely in temperate climates that the air in the mine will be warmer in winter and cooler in summer than that outside. Hence the draught will be in winter out through the highest opening, and in summer the reverse, while periods of stagnation will occur in spring and autumn. The natural draught may be assisted by wise choice of the localities for the openings, or by use of weather-caps and chimneys over the upcast; but these aids are not effective except where the intake is an adit. Artificial ventilation is effected by increasing the difference of temperature between the entering and the escaping air, so as to render the currents comparatively independent of the weather, or by increasing mechanically the difference in density. In the first class of instances, either the escaping air is warmed, or the entering air is cooled; in the second class, either the escaping air is rarefied by suction, or the entering air is condensed by blowing. The escaping current may be warmed by connecting the upcast with the chimney of a steam-boiler above ground, or with a special furnace above ground, or by means of a furnace in the shaft, or near the bottom of it, or by introducing steam-jets into the shaft. The jets have a mechanical as well as a thermal effect; but the total effect per pound of coal consumed is less than that of the furnace. The cooling of an entering current of air is sometimes effected by allowing water to fall into the downcast, and is also an incidental effect of the water-blast or hydraulic bellows, a simple contrivance by which a falling stream carries a draught of air with it into a receiver, where the air is disengaged from the water, and forced, under a pressure due to the water column, into the mine. Ventilating machines (exhausting or blowing machines) are used almost exclusively in coal-mines, where a great excess of air, to dilute injurious gases, is a vital necessity. These ventilators are either reciprocal (pumps) or rotary (fans). The latter are generally employed, and for extensive ventilation the exhausting fans are usually preferred to the blowers. One of the most effective fans, Guibal's, gives, with a diameter of 14.34 ft. and 8 arms revolving 134 times per minute, a current of 929 cub. ft. of air per second. The distribution of the air-currents through the mine, so as to bring fresh air to the workmen, and remove all foul gases to the upcast, is very important, and requires a system of air-courses, doors, etc. Portable lights in mining are torches, candles, and oil safety-lamps. (See LAMPS.) Stationary lights are also employed (lanterns with oil or petroleum, gas-light, and various electric lights) for illuminating permanent roadways, landings, etc. The drainage of mines is effected by natural means (through adits) or by means of pumps or buckets. These are sometimes operated by hand- or horse-power or wind, more frequently by hydraulic engines, and most frequently by steam.

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See also "Transactions" of the American Institute of Mining Engineers, of the North of England Institute of Mining Engineers, of the Institute of Mechanical Engineers, and of the South Wales Institute of Mining Engineers; also files of *Engineering and Mining Journal*, *Iron Age*, *Mining and Scientific Press*, and the English *Mining Magazine*, *Mining Journal*, and *Iron*.

MINING, HYDRAULIC. Hydraulic mining, in the broadest sense of the term, may be defined as the art of separating gold from a great variety of auriferous material, through the agency of water under great pressure, discharged through pipes against the deposits to be acted upon.

The prerequisites to profitable hydraulic mining are: first, a supply of good gravel; second, a sufficient quantity and head of water to work advantageously; third, an ample grade to run off the material; and fourth, plenty of dump-room to dispose of the detritus. There must be a sufficient supply and pressure of water, not only to do the work of cutting down the banks, but also to carry off the material. The grade must be steep enough to carry the tailings through the sluices, and the dump must be extensive enough to receive the accumulations not only of a month or year, but of several years. In the workings of every department economy is absolutely essential to success, as the amount of gold collected per cubic yard of material moved is very trifling, and remunerative returns can only be secured by washing large areas of ground at a minimum of cost. In order to insure a continuous supply of water throughout the year, some of the most extensive constructions

HYDRAULIC MINING.

of modern times have been made by corporations calling themselves "ditch companies," who erect dams to hold the water in reservoirs, open canals, build flumes, and use the water upon claims of their own and sell their surplus to other companies at so much per miners' inch.

Measurement of Water.—The miners' inch is an arbitrary measurement of water established in early days among the various mining camps, each of which made its own laws on the subject without reference to what had been done elsewhere. Unless, therefore, the local conditions regulating the sale of the same are stated, the miners' inch becomes an unknown quantity. As accepted in some districts, it is an amount of water discharged from an opening 1 in. square through a 2-in. plank with a pressure of 6 in. above the opening. The amount of water that will pass through any orifice in a given length of time is dependent upon the head or pressure above the aperture, and the thickness of the timber through which the aperture is made. The flow of water will therefore change with the varying of these dimensions. The Smartsville inch is calculated from a discharge through a 4-in. orifice with a 7-in. head, the plank being 1 in. thick. To secure a supply of 100 in., the aperture would be made 4 in. wide and 25 in. long. This will admit of a discharge of 1.76 cub. in. of water per minute for each square inch of opening, or a total of 2,534.40 cub. ft. in 24 hours.

The South Yuba Canal Company's inch is calculated from the quantity that will flow through a 2-in. aperture, cut in a 1½-in. plank, with a pressure of 5 in. above the opening. From a number of careful experiments made at the North Bloomfield, Milton, and La Grange mines, using as a module a rectangular slit 50 in. long and 2 in. wide, with a pressure 7 in. above the centre of the opening, the following results were obtained: 1 miners' inch will discharge in 1 second .2624 cub. ft.; in 1 minute, 1.5744; in 1 hour, 94.4640; in 24 hours, 2,267.1360. Ratio of actual to theoretical discharge, 61.6 per cent. The above experiments were made under the personal supervision of Hamilton Smith, Jr. Later experiments, made by Aug. J. Bowie, Jr., at La Grange, to determine the effective value of the above-described inch, gave the following results: 1 miners' inch discharged in 1 second, .2499 cub. ft.; in 1 minute, 1.4994; in 1 hour, 89.9640; in 24 hours, 2,159.1460. Ratio of effective to theoretical discharge, 59.05 per cent., which is equivalent to about 93 lbs. of water per minute. These results form a general basis of calculation, to which the other systems are referred when accuracy of measurement is desired, or legal controversies are to be adjusted.

Storage Reservoirs.—The California year is divided into two distinct seasons, known as the wet and the dry. During the former, which begins generally in November and lasts until May, the average rainfall throughout the State amounts to about 20 in., while for the rest of the year it is inconsiderable if not wanting altogether. In order, therefore, to secure a continuous supply of water, the mining or ditch companies have been forced, at enormous expense, to occupy the natural mountain basins, or create artificial ones, for storage purposes. These basins often embrace bare mountain slopes and valleys, into which drains the water dropping from the clouds or running from the melting snow, with a minimum of loss by evaporation or absorption. The catchment area varies with the location from 1 to 50 square miles. The reservoirs are made of sufficient capacity to store not only the regular supply from the above sources, but the volumes that result from cloud-bursts or sudden freshets. The most complete system of reservoirs ever established for the storage of water for hydraulic-mining purposes are those of the North Bloomfield Company. The capacity of the Bowman reservoir, added to that of the others in connection with it, is about 1,000,000,000 cub. ft. of water. The cost of these, including dams, etc., has been nearly $250,000. The Rudyard reservoir, of the Milton Company, formed by three dams, the highest of which is 100 ft., at a cost of $150,000, contains 535,000,000 cub. ft. of water, or 3,980,000,000 gallons. The French, Weaver Lake, and Faucherie reservoirs, of the Eureka Lake and Yuba Canal Company, have an aggregate capacity of about 820,000,000 cub. ft. Independent of these are the reservoirs for distributing, which will be described later.

Dams.—The dams that have been referred to in connection with reservoirs differ materially in their form and manner of construction, which are almost as numerous as the engineers engaged to design and build them. They may be of stone, earth, or timber, or a combination of these materials. Fig. 3093 represents a section of a timber-crib dam, 90 ft. high, formed of cedar and tamarack logs, firmly notched and bolted together. At the bottom of the incline are located a protection and strainer to the inlet. At the back are set the gates opening into the flume. This dam was designed to hold in place 7,000,000,000 gallons of water, and to resist a maximum pressure of 12,000 tons.

3093.

Among a large number of dams built by the Tuolumne County Water Company of timber cribs, that across the south fork of the Stanislaus River is worthy of special notice. It was built by the aid of large derricks and at an expense of about $40,000, in the year 1856, since which time it has not required any expenditures for repairs. It is 300 ft. wide at the top, 60 ft. high, and forms with the surrounding slopes a reservoir of 800 acres area, at an elevation of about 8,000 ft. above sea-level. It rests upon solid rock foundations, and is built of round tamarack logs from 2 to 3 ft. in diameter, formed into cribs about 8 ft. square, pinned together by wooden treenails. The water-face is inclined at an angle of 50° with the horizon, and is made up of flattened 8-inch timbers, pinned with wooden treenails to the crib and calked with cedar bark. At different elevations along this face dis-

charge-gates are placed, through which the water flows from the various levels of the reservoir into the head of the supply-ditch. Pine dams, constructed on the same plan and about the same time, have long since decayed and broken down, or been replaced by hard-wood dams such as above described.

Among the principal dams built of dry rubblestone and faced with a water-tight lining of plank, are the Eureka Lake dam of the Eureka Lake and Yuba Canal Company, with a height of 68 ft., high-water area 328 acres, storage capacity 680,000,000 cub. ft., catchment basin 5.1 square miles; the Fordyce dam of the South Yuba Canal Company, with a height of 60 ft., and a catchment basin of about 40 square miles, built at a cost of $160,000; and the three dams owned by the Milton Mining and Water Company, forming the English reservoir. The largest of these has a height of 131 ft. from base to summit, and has a capacity of 618,000,000 cub. ft. of water, an area of about 400 acres, and is fed from a catchment basin of 12 square miles. The Bowman dam is by far the largest of its kind on the Pacific coast. It was designed by Mr. Hamilton Smith, Jr., C. E., the engineer of the North Bloomfield Company, to hold not only the drainage of its own water-shed, but the accumulated volumes resulting from an accidental tearing away of the upper dams, from cloud-bursts, or other sudden rush of water from freshets. The dam was built to a height of 72 ft. during the year 1872, with foundations upon solid granite. It was placed across a cañon where the flow of water from a natural stream amounted to a maximum of from 5,000 to 7,000 cub. ft. a second, and an additional influx of many times as much would be caused by the giving way of the upper dams.

Mr. Smith says of the dam: "It was built in the year 1872 to the height of 72 ft., being a timber crib formed of cedar and tamarack unhewn logs, firmly notched and bolted together and solidly filled with loose stone of small size. A skin of pine planking spiked to the water-face formed its water-tight lining. During the years 1875 and 1876 the dam was increased to a height of 96½ ft. above datum line (100 ft. extreme height) by filling in a stone embankment on the lower side of the old structure, faced with heavy walls of dry rubble-stone of large size. The down-stream face-wall is 15 to 18 ft. thick at the bottom, diminishing to 6 or 8 ft. at the top. Most of the face-stones in this wall are of good size, weighing from three-quarters of a ton to 4½ tons, and there are many stones of equal weight in the backing. The lower portion of the wall is 17½ ft. high, with a batter of 15 per cent. It is built of heavy stone with ranged horizontal beds, and with the face-stone tied to the backing with long iron clamps. The upper portion of the wall is built with a slope of 45°, and the face-stone are bedded on an angle of 22½°, thus dividing the angle between a horizontal bed and a bed at right angles to the face. No attempt at range-work was made in the upper portion of the wall. Above the 68-ft. line, ribs of flattened cedar 8 in. thick are built into the up-stream face-wall, and are tied to it by iron rods three-quarters of an inch in diameter and 5 ft. long. To these ribs a planked skin is firmly spiked. This planking is of heart sugar-pine, 3 in. thick and 8 in. wide, with planed edges fitted with an outgage similar to ship-planking. The plank was put on nearly thoroughly seasoned, and swells sufficiently to make the face practically water-tight, without either battens over the joints or calking. The openings at the joints, made by the outgage, suck in small particles of vegetable matter, which take the place of calking to a large extent. At the bottom the planking is fitted closely to firm bed-rock and calked with pine wedges. There will be three thicknesses of plank (9 in. in all) placed on the lower 25 ft., two thicknesses (6 in.) on the next 35 ft., and one thickness on the upper 36 ft. From past experience it is believed that this planking will remain sufficiently sound for 20 years. A culvert extends through the dam, through which the water is drawn from the reservoir. This culvert is built with heavy dry rubble foundation and walls, and is covered with granite slabs 16 to 18 in. thick and 6½ ft. long. Three wrought-iron pipes of No. 12 iron, each 18 in. in diameter, pass through the water-face of the dam. Their upper mouths are protected by a strainer formed of 2-in. plank, anchored to the bed-rock. A separate valve or gate is placed at the lower end of each pipe; the water passing through the gates, aggregating a flow of 280 cub. ft. per second, discharges into a covered timber-sluice 7½ ft. wide, 1¾ ft. high, passing to the lower edge of the dam, and discharges on the solid rock of the creek-bed. The gates are approached by a man-way above the sluice. The crest of the dam will be formed by a coping of hewn heart-cedar timbers, 18 in. wide on top, and anchored securely by iron bolts to the stone wall below. It is not probable that any water will ever pass over the crest of the main dam; but should a break occur at the large reservoir higher up the stream when the waste-gates at the waste-dam are closed, the difference in level between the crests of the main and the waste dams might be insufficient to allow the resulting flood to pass over the waste dam. Additional care was therefore taken in building the down-stream face-wall of the main dam, so that it can in any such possible emergency resist without injury a large stream of water passing over the crest. Should this happen, a large quantity of water would enter the structure, owing to the inclined beds of the face-stone and the flat slope of the wall, which would seek its discharge through the interstices purposely left in the nearly vertical portions of the lower wall. To prevent the consequent hydrostatic pressure, which would accumulate at the base of the dam to perhaps 20 lbs. to the square inch, from forcing out the lower face of the wall, it was carefully built and tied with iron rods. There are 55,000 cubic yards of material in the structure, weighing about 85,000 tons. The hydrostatic pressure, with the water-line 95 ft. above datum, against a vertical plane of that height across the cañon at the dam site, will be 21,745 tons. The dam is built V-shaped, with the vertex of the angle of 165° pointing up stream. This mode of construction adds somewhat to the stability of the structure. The cost of the dam when completed will be about $132,000."

The flat slopes adopted in the construction permitted the use of a large supply of loose stone readily accessible, and lighter facing stone than would have been required had these slopes been more nearly vertical, which resulted in the ultimate saving of many thousands of dollars in the cost of raising the dam.

DITCHES.—So much of the success of a hydraulic-mining enterprise is dependent upon a regular supply of water, that no pains or expense have been spared in the construction of ditches that lead

from the mountain reservoirs to the various auriferous deposits found in river-channels, in basins, or on flats. These ditches, aggregating over 7,000 miles in length, have been constructed at an expense of over $25,000,000. While an approximate estimate of the value of hydraulic claims in California, with their ditches and improvements, would not fall much short of $100,000,000, it is stated by competent authorities that hydraulic and drift mining together have added over $300,000,000 to the wealth of the State.

In the location of a ditch, a number of important points are to be considered. It should be laid upon an average grade of about 15 ft. to the mile, and, wherever possible, along the mountain-side fronting to the south, in order to avoid accidents resulting from break-ups in the spring, through the movements of the melting snows or departure of the frost from the ground. All trees within a few feet of the upper bank should be cut down, and leaves, logs, and underbrush removed. It should be located with especial reference to maintaining a continuous and uniform supply of water during the working months; and to aid in effecting this, streams along the route should be tapped wherever practicable, to make up the loss due to leakage and evaporation. Waste-gates should be erected at proper points to relieve the ditches of extra pressure when thaws or heavy rains have flooded the country and run them full of water. In order to retain the maximum hydrostatic pressure up to the very moment when it is to be utilized, the ditch is kept upon the highest possible ground consistent with grades and lines of detour adopted. It should be made deep rather than wide, to avoid excessive evaporation or loss by leakage through the ground. It should not be built upon very steep inclines, nor located so far from the natural slope that it is difficult to secure a strong outside bank of earth. In a case of doubt, it is preferable either to adopt masonry aqueducts or run a flume for a short distance. The experience of ditch-builders in California has developed a practice there which differs materially from the plan of action formerly adopted. Grades have been increased to even 25 ft. per mile, and the carrying capacity to 60 cub. ft. per second; but old prejudices are hard to get rid of, and these innovations have not been universally adopted as yet. On account of the deep snows and heavy storms of winter, they have been found safer and more economical to operate.

The following table shows the dimensions of some of the most important ditches in California:

NAME OF MINE.	Length of Ditch.	Top of Ditch.	Bottom of Ditch.	Depth of Ditch.	Cost of Ditch.	Average Grade per Mile.	Discharge in Miners' Inches.
	Miles.	Ft.	Ft.	Ft.		Ft.	
North Bloomfield.....	55	8.65	5	3.5	$422,000	14	3,200
Milton Company.....	100	6	4	3.5	259,000	143	3,000
Eureka Lake.........	18	..	..	...	480,000	...	2,800
San Juan............	45	..	..	...	298,000	. .	1,800
Excelsior............	83	8	5	4	......	9	1,700
Union...............	15	8	4	3.5	......	13	1,200
Boyer...............	15	8	4	3.5	......	18	1,200
Spring Valley*......	52	6	4	3.5	......	...	2,000
Hendricks...........	46.5	6	4	2	186,000	9.6	....
La Grange†..........	20	9	6	4	450,000	7.5	3,000

In crossing ravines, passing along the abrupt faces of precipices, or connecting the ditch with the bulkhead, flumes are commonly used, although they are objected to on account of the danger from fire and cost of repairs. They are set on straight lines or very easy curves, and are of smaller area than the ditches with proportionally heavier grades. The grades sometimes reach even 35 ft. per mile. Owing to the great irregularity of surface, many of these ditches have miles of fluming. The ordinary style of construction is shown in Fig. 3094. The planking is commonly of heart sugar-pine, 1¼ to 2 in. thick and 12 to 18 in. wide. To effect a good seam, pine battens 3 in. wide by 1¼ in. thick are placed over the joints. Bents of square timber well mortised together, set from 4 to 6 ft. apart, support and strengthen the flume. The posts spread out toward the bottom, so that the sills are somewhat longer than the caps, and they are generally sawed so as to extend about 2 ft. beyond the foot of the posts. Where a flume is carried along the steep mountain-side, it is secured to the solid bed of rock as shown in Fig. 3095. They are set in as close as possible to the bank, as a precaution against accidents from storms, winds, or snow-slides.

Wrought-Iron Pipes.—As the importance of hydraulic mining began to be recognized, and the necessity of securing some means for conveying water across deep ravines and through very rough and broken districts of country not adapted to the erection of flumes, sheet-iron pipes were introduced on account of their lightness and great tensile strength. They have been made of No. 16, 14, and 12 Birmingham gauge, from 11 to 40 in. in diameter, 20 ft. long, and riveted in the horizontal seams, but put together in stove-pipe fashion, without rivets or wire to hold the joints in place. As floating particles of matter readily render the joints comparatively water-tight even under a pressure of 200 lbs. to the square inch, it is only under high heads and sudden shocks that lead joints such as shown in Fig. 3096 are used. The lead is forced, as at *b*, between the iron sleeve *a* and the pipe, while *c* is an internal flange bolted to one length of pipe in such a way that the other fits over it. The spacing of the rivets has proved to be a matter of considerable importance. For example, a pipe 12 in. in diameter, made of No. 18 iron, was formerly riveted in the longitudinal seams every 1 to 1¼ in., while the round seams have been left pretty open, with rivets set 3 in. apart. Now, in the better class of pipe adopted, the round seams are made with rivets three-quarters of an inch apart, and the longitudinal seams are double-riveted, with rivets 1 in. apart in the row, and about half an inch apart from one row to the other. If such pipes are dipped in asphaltum to protect them from the weather, they will last for many years. The thickness of the iron is usually proportionate to the head

* This has 8½ miles of 30-inch iron pipe.

† Most of this ditch is hewn out of granite.

of water and the diameter of the pipe. Pipes made of the different sizes of iron here mentioned will stand the following s.rains per sectional inch:

No. of Iron.	Strain, Lbs.
12	7,000 to 9,000
12 to 9	9,000 to 12,000
9 to $\frac{3}{16}$	12,000 to 14,000
$\frac{1}{4}$ to $\frac{3}{8}$	17,000 to 18,000

The head of the water in pounds avoirdupois, multiplied by the diameter of the pipe in inches and divided by the above coefficients, gives twice the thickness of the iron to be used. Allowance must be made for the security required; that is, if the breakage of the pipe will cause much damage, it is advisable to lower the margin for greater safety. The diameters of the rivets used are: No. 18, $\frac{3}{16}$ in.;

3094.

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No. 16, $\frac{7}{32}$ in.; Nos. 14, 12, 11, $\frac{5}{16}$ in.; Nos. 10, 8, 7, $\frac{3}{8}$ in.; $\frac{1}{4}$ in., $\frac{1}{2}$ in.; $\frac{5}{16}$ in., $\frac{5}{8}$ in.; $\frac{3}{8}$ in., $\frac{3}{4}$ in. They are usually spaced to make the pipe tight, that is, closer than is necessary for the strength of the seam; but this in turn is governed by the pressure on the pipes. The following table shows the usual distances of rivets for corresponding thickness of iron, with 22-inch wrought-iron pipe:

Thickness of Iron.	Diameter of Rivets.	Length of Rivets.	Pitch of Circle Seams.	No. of Rivets in each Circle Seam.	Pitch of Rivets in Longitudinal Seams or Double Row.	Width between Centres of Rivets in the Double Row.
	In.	In.	In.		In.	In.
No. 12	$\frac{5}{16}$	$\frac{3}{4}$	1	60	$1\frac{3}{4}$	$\frac{3}{4}$
No. 11	$\frac{5}{16}$	$\frac{3}{4}$	1	60	$1\frac{3}{4}$	$\frac{3}{4}$
No. 9	$\frac{3}{8}$	$1\frac{1}{16}$	$1\frac{1}{16}$	50	$1\frac{7}{8}$ full.	$\frac{7}{8}$
$\frac{3}{16}$ in.	$\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{16}$	50	$1\frac{15}{16}$ full.	$1\frac{1}{16}$
$\frac{1}{4}$ in.	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{5}{16}$	50	$1\frac{15}{16}$ full.	$1\frac{1}{16}$

When the pipe is made and put in position, air-valves are located at each summit and blow-valves at each depression, as the pipe is carried over a number of low ridges or shallow ravines. The air-valves are designed to allow the escape of the air from the pipe while filling, and to prevent any collapse should a break occur. The blow-valves are arranged to blow off or discharge at a certain pressure, and thus avoid excessive strains on the pipe and consequent ruptures. A very effectual way of preventing air from entering the pipe along with the water, is to put a gate in the pipe a little below the level where the water enters it. By this means of control the flow of water can be regulated at will, and a steady pressure can be obtained, that is entirely free from those violent oscillations so objectionable. Where the water enters through a funnel-shaped pipe, it is pretty effectually cleared of air at the outset. Should any enter by accident, it is frequently removed through an air- or stand-pipe put in at some distance from the inlet.

Of late years, where valleys and great depressions of wide extent have had to be crossed, and the sources or heads of the ditches have been too remote to follow around on the necessary grade, wrought-iron pipes of the heaviest character have been brought into service. The Cherokee Flat Mining Company, of Yuba County, Cal., overcomes a depression of between 800 and 1,000 ft. with such piping. The water is carried in a ditch or flume to a point on one side of the depression 980 ft. higher than the lowest point where the crossing is effected. A wrought-iron pipe receives the water, carrying it down the slope of the mountain to the bottom, thence up the opposite side to a vertical height of 830 ft., where the water is discharged into a ditch or flume and carried to the mines for use. Until the project for supplying Virginia City, Nevada, with water was inaugurated in 1872

(see AQUEDUCT), this pipe was sustaining the heaviest pressure of any of its kind in the world. Now much higher pressures have been successfully provided for.

WORKING.—The water, finding its way out of the reservoir, through flumes, ditches, and pipes, along mountain-sides and cliffs, over rivers, valleys, gorges, trestle-work, and suspension bridges, finally reaches the distributing reservoirs, from which it is drawn to the various claims. These reservoirs are located with especial reference to accessibility, capacity, head secured, and economy of construction. They are generally artificial basins made by excavating material from within certain limits and using it to create an embankment. From the distributing reservoirs the water is conveyed through pipes, ditches, or flumes directly to a box, Fig. 3097, called a bulkhead or pressure-box, situated above and in close proximity to the material to be washed. This pressure-box is very strongly built, and made of a sufficient depth to keep the top of the pipe covered with several feet of water. A grating at G, where connection is made with the flume, prevents the choking of the pipe by sticks, leaves, or other organic matter. In case of accident to the pipe F, which is swelled to a funnel-shape for connection with the bottom of the box, the water can be discharged through a gate at the side as shown. The flow of water to the distributors on the lower end of the feed-pipe is regulated by the valve set just below the pressure-box, operated through the spindle B. This pipe varies in thickness and diameter with the hydrostatic pressure and the quantity of water to be used. In picking out a suitable route for this pipe from the pressure-box down to the claims, all angles and depressions should be avoided, and the line made as direct as possible. Automatic air-valves should be arranged at proper points, to allow the escape of air when filling the pipe, and also to prevent

3098.

any collapse from atmospheric pressure should a vacuum occur. Where the descent is precipitous, the pipe is sometimes carried on an inclined trestle, well braced to prevent any movement or sliding of the column. Frequently, in addition to this framework, stones are used to weight down the structure and hold the pipe in place. When the level of the workings is reached, it is again secured by proper braces and weights (see Fig. 3098). In any event the pipe F leads directly from the bulkhead D to a distributing box B, located in the workings below and as near the banks as consistent

with the head and volume of water to be used. The pipe *F* is made in 12-ft. lengths, and is joined stove-pipe fashion. The joints are lapped from 2½ to 3½ in., with longer laps at intervals to allow for expansion. When it becomes necessary to join these lengths more effectually together, it is done by passing wire around lugs attached to the ends of the same. In filling the feed-pipe, the water is turned on gradually to avoid sudden shocks and straining of the column. Leaky joints are closed by running a few bags of sawdust through the pipe, and by wedging them with thin pieces of soft pine.

The distributing boxes are of various forms and designs. Fig. 3099 illustrates a V-distributing box for two branch-pipes. *A* is the inlet-pipe from reservoir; *B B* are outlet-pipes to nozzles; *C C* are wheels to elevate the valves; *D D* are valve-boxes; *F* is the pressure-gauge, made of cast iron, and of sufficient strength to resist the pressure of water under a great head.

From the distributing box the water is led directly to the discharge-pipes. These discharge-pipes are known among miners as "Hydraulic Chiefs," "Monitors," "Little Giants," etc. Of these the "Little Giant" is shown at Fig. 3100. It has a complete horizontal movement on the plane *B B*, and a vertical one on a knuckle-joint *E*, which is counterpoised at *I* to keep it in position. It is exceedingly simple, easily repaired, has no abrupt angles, and it is claimed discharges a larger amount of water with less resistance than any other. To prevent wearing, the joints are packed water-tight with leather. As the effectiveness of the stream depends upon the preservation of its rotundity of form, the nozzles are provided with three internal riffle-plates, that break up any tendency on the part of the current toward a rotary motion. Of the other nozzles in use, that known as the "Dicta-

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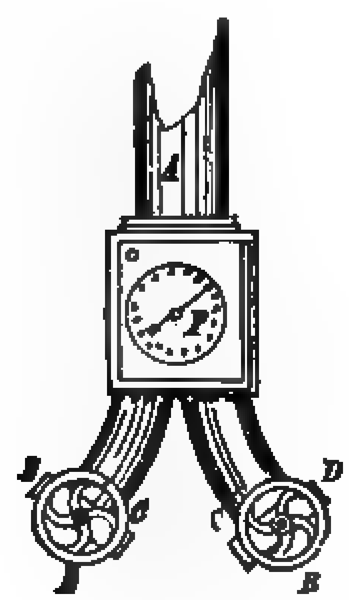

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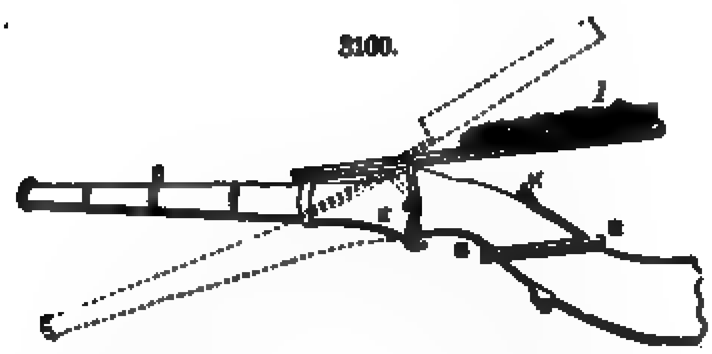


tor," the invention of Mr. Hoskins (who was also the originator of the "Little Giant"), Craig's "Globe Monitor," and Fisher's "Hydraulic Chief" are considered the best and most serviceable. These pipes with nozzles vary in length and diameter, the largest size in use being 15 ft. long and 9 in. in diameter at the outlet. They are used in pressures ranging from 150 to 375 ft., discharging water at velocities from 75 to 180 ft. per second. The largest pipe on record is under a 375-ft. head, discharging 36,000,000 gallons every 24 hours.

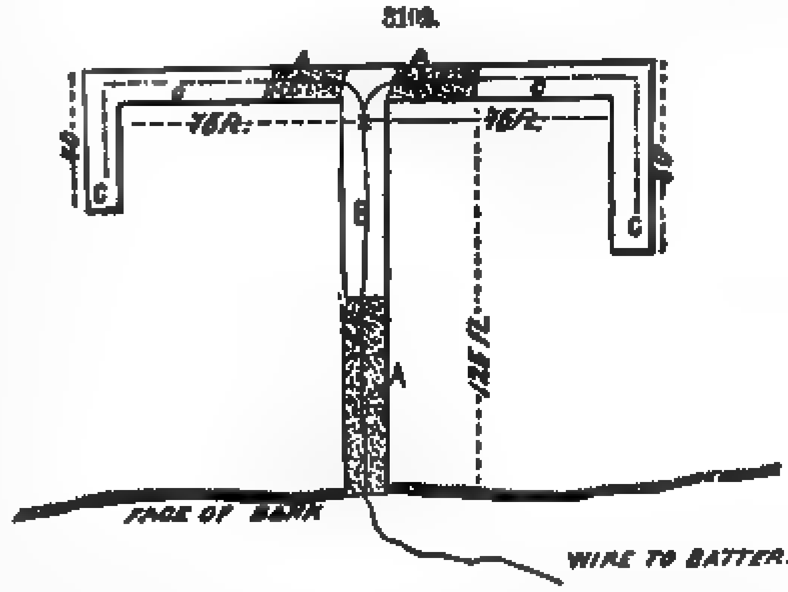
The amount of material that can be washed from a gravel-bank and sluiced off, per miners' inch of water, depends upon the location, grades, dump, etc., as well as upon the nature of the material. It varies from 1 to 6 cubic yards per miners' inch. In general, however, when making an estimate of the amount of water required to work off any particular bank of gravel, the calculation is made upon a basis of not less than 20 cubic feet of water to work off 1 cubic foot of gravel.

During the construction of the dams, ditches, flumes, etc., to insure a definite and regular water-supply, ample dumping ground to receive the accumulations of several years' washings has been secured, the prospectings carried on energetically, the tunnel site selected, the bed-rock reached and inspected, and connection made with the surface through a vertical shaft, upraised from the tunnel-line. A section of the ground and layers encountered in opening a shaft on one of the claims of the North Bloomfield Gravel-mining Company is shown in Fig. 3101. From this prospect-shaft drifts were run aggregating 2,000 ft. along the channel, which was estimated to carry a width of

about 500 ft. The gross cost of the entire prospecting work was $63,956.20. As soon as the depth and position of the bed-rock, the direction of the channel, and the value of the gravel had been determined, a working tunnel was located. This is generally requisite to sluice off the gravel, as it is seldom practicable to run open cuts sufficiently deep in the bed-rock to bottom the channel. When therefore the working tunnel has been run well into the claim, and opened throughout to a size to suit the flumes—viz., 5 × 7 for a 4-foot flume, and 8 × 8 for a 6-foot flume—and the shaft opened to the surface, it is carefully timbered throughout. It should not be less than 5 ft. by 9, to allow of two compartments being laid off, one of which is used by the miners in ascending or descending, and for effecting repairs when accident closes the other or working compartment. From the foot of this vertical shaft the sluices, set on the proper grade, lead off the material through the tunnel, over the riffles charged with quicksilver, and finally to the dump.

When everything is ready for working, some of the upper timbers of the shaft are removed, the ground around the mouth shaped to the form of a terrace, and the washings run into the shaft as rapidly as possible, to admit of the introduction of one or more "Little Giants." At the start one nozzle is used to cut down the bank, the other to run off the débris; but as the workings enlarge, another pipe is added, and the two cutting nozzles play heavy streams upon the bank at a considerable angle between them. When the stream first strikes the bank, the water is scattered in every direction; but it soon buries itself, and exhausts its whole force in extending the arched cavity both laterally and in depth. The miner knows from experience just how deep to make this cavity. When the nozzle can no longer be used to advantage at this point, it is moved, another arch is formed, and so on until enough have been made to cave the bank as soon as the walls between have been cut away. The caved material is then washed as uniformly as possible into the shaft, from which it passes into the sluice-boxes. All the material left behind which is too large to be carried off is broken up with the hammer or blasted with powder. Where the ground is very hard, recourse is had to blasting to assist in breaking up the gravel and cement deposits. To accomplish this, a tunnel is run into the bank to strike through the rim-rock and into the channel just above the bed-rock. From a point located pretty centrally in the hard material, lateral drifts are sent to the right and left for about 100 ft. each in the direction of the channel walls, and from the ends of these short subsidiary drifts, as shown in Fig. 3102. Large quantities of powder are in the lateral and subsidiary drifts, as at *C*, and in the main tunnel, as at *B*. At *A A A* the lateral drifts and tunnel are carefully closed by a considerable volume of earth, and the whole mass of powder exploded simultaneously, through a system of wires connected with an electric battery. In this way immense banks of profitless gravel are made available. Worthless material must be gotten rid of as quickly and economically as possible, by moving it immediately to the point of deposit where it is to remain. Wherever possible, three or more nozzles should be connected to the same distributor, as is the case at the North Bloomfield workings. Here the feed-pipe is 1,200 ft. long and 40 in. in diameter. The nozzles used are 6 in. in diameter, the head 240 ft., the pressure in the pipe 108 lbs. per square inch, and the nozzles discharge each 1,300 cub. in. of water every 24 hours.

3102.



The sluices are laid in as straight a line as possible, with the outer side of the box slightly raised to cause a more uniform distribution of the materials over the riffles. They are commonly made of 1½-in. plank, tongued and grooved, although, to secure a perfect fit, the planks should be grooved and then joined together by driving in a soft-pine tongue. A framework of 4 × 6 in. scantlings, made up of a sill, upon which the box rests, and two posts on either side, carefully fitted to the sills and braces, connecting the ends of the sills and posts together, is set every 4 ft. for additional strength and security. The size of the sluice is determined by the quantity of water secured, character of gravel to be washed, and grade adopted. A sluice 3 ft. wide and 30 in. deep, with a 1½ per cent. grade, has a carrying capacity for 800 to 1,000 miners' inches of water; one 6 ft. wide and 36 in. deep, on a 5 per cent. grade, 3,500 miners' inches of water. The length of the sluice is dependent upon all the conditions above enumerated, the desideratum being to insure the complete disintegration of the material and separation of the gold. The bottom of the sluice is lined with square blocks of suitable length and breadth, 8 to 12 in. deep, called riffles, with spaces of from 1 to 1½ in. between

3103.

each cross-row. They are commonly held in position by means of soft-pine wedges, driven between the blocks and sides of the sluice. The old method of fastening small boards on the bottom crosswise between the rows, as shown at *A*, Fig. 3103, has fallen somewhat into disuse, and the wedge system shown at *C* has been pretty generally adopted. In some localities, where wooden blocks can be secured only at considerable expense, round cobble- or field-stones are often used. A combination of the two systems, a row of blocks alternating with an equal section of rocks, has proved very satisfactory in materially reducing the wear and tear of the blocks. Where clean-ups are frequent, they have not been adopted owing to the expense connected with repaving. Rock-riffles alone require more water and steeper grades than those consisting of wooden blocks. The only objection to the use of wooden blocks is the cost of wear and tear. It is generally preferable to set the block-riffles near the head of sluices where a large amount of gold is collected and the clean-ups are frequent.

The sluices are commonly discontinued at the mouth of the tunnel, from which point for several thousand feet down the ravines or creek-beds the water is conducted over undercurrents or other gold-saving appliances to the final outlet or river-channel below. One form of undercurrent that has given good satisfaction is shown in Fig. 3104. The grade of the sluice *A*, leading from the tunnel or diggings, may vary from one-third of an inch to one inch to the foot. From this point down the creek-bed the undercurrents are placed at proper intervals. In the bottom of the flume *A*, near the point of discharge, a "grizzly" of wooden bars covered with iron plates, or entirely of iron, is placed, with sufficient space left between the bars to precipitate all but the coarsest material into the box below. The bowlders, large pebbles, etc., go directly to waste over the grizzly. The eliminated material and water is cast upon and spread over a large platform *B*, four or five times the width of the sluice above, and as long as circumstances will admit. While the grade is steeper, the velocity of the water is sensibly checked. Riffles, made in sections for convenience in removing and cleaning, are placed in the bottom. A portion of the débris and presumably all the gold that has escaped lodgment or amalgamation, together with a portion of the water, are spread over *B*. The depth being materially decreased, some particles of gold that have been kept in motion by the velocity of the water and débris in the main flume come to rest, and the lighter earthy matters with some gold pass on. Sometimes, where the fall will admit, a second undercurrent is placed below the first, as shown at *C*, with a second and finer grizzly, as at *D*, the waste material passing off at *E*, and the sand, with any free gold or amalgam that may have escaped the upper undercurrent, passing into box *F*, which contains riffles *G* across the bottom, where it is caught and retained. Undercurrents are used quite extensively at present in the working of tailings.

After the sluices have been run a half day, they are considered packed; and as soon as the water begins to clear from a temporary stoppage of the washings, the regular charge of quicksilver is added and the washing resumed. This operation is repeated on the second and third days, until the riffles hold the mercury at the surface. The amount subsequently added is regulated by the quicksilver exposed to view, and depends to a large extent upon the length of the run. This will average about 20 full days. A longer run is apt to result in a waste of amalgam, which becomes hardened and is liable to pass away with the débris. The blocks, riffles, and flumes have also become worn and require overhauling and repairing. As soon, therefore, as the time arrives for cleaning up, the streams of water are used to wash the last particles of loose earth into the sluices. Clear water is then passed through the sluices, and the work of removing the riffle-blocks begins. They are pried out with the aid of heavy iron bars, and carefully washed. If they are much worn, they are reduced to ashes and returned in this changed form to the flumes; if not, they are laid aside to be used again. While the above has been in progress, the flow of water has been brought down to about half an inch over the bottom of the flume. The amalgam that had formed during the run, and collected between the blocks, is cleansed by the action of the clear water, and, in irregular-shaped masses of a semi-plastic consistency and bright silvery lustre, awaits removal. This gold amalgam, containing hundreds of thousands of separate particles of the precious metal, is now scooped into sheet-iron buckets, and carried to the retort-room, where the quicksilver is removed by heat, collected under water, and used over again, while the bullion is remelted, assayed, and cast into ingots for commercial purposes. The excess of quicksilver remaining in the flume after the removal of the amalgam is scooped into buckets and used in the next run.

The aggregate loss of quicksilver in several mines for a period of several years, where a record was kept, was as follows: 3,931,367 cubic yards of material moved by 2,784,450 miners' inches of water, with a loss in quicksilver of 4,351 lbs., or 1 lb. of quicksilver to 900 cubic yards of gravel and 640 miners' inches of water. The loss of gold in hydraulic mining can only be arrived at approximately, as the tailings are frequently considered of too little value to pay for handling. Where, however, the tailings have been saved and carefully worked, the result showed a loss from the first workings of not more than 2 per cent. What was lost in the second workings through flower gold was not determined. In altering the grades to save this class of gold, the working capacity of the flumes is decreased to such an extent that no definite move has been made in this direction; but this and other important matters are now (1879) in course of investigation by scientific experts, who have made and still are making valuable improvements in the line of efficiency and economy. Water, that formerly cost 50 cts. per day for a miners' inch, can now be secured at rates ranging from 2 to 10 cts. per inch.

The saving appliances now in use have increased the yield of gold per inch to $1 or even $1.50. In addition to those of a mechanical nature already referred to are a number illustrated below. Figs. 3105 and 3106 show a "hurdy gurdy" water-wheel used in converting water-power into that derived

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3108.

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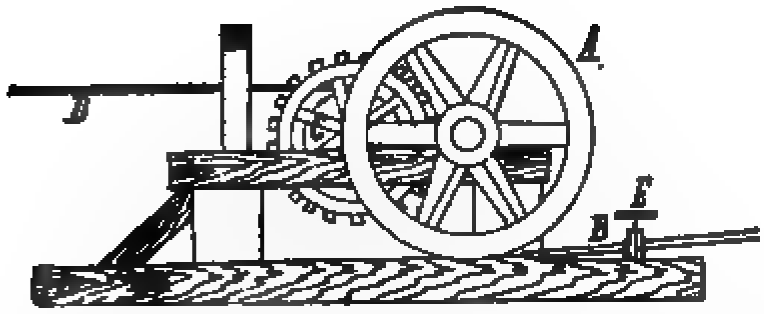

from the use of compressed air, etc., to aid in the driving of drifts, tunnels, etc., by means of power drills of various kinds. It is claimed that an 8-ft. wheel under a 200-ft. head, using 100 miners' inches of water, will furnish about 50 horse-power at 175 revolutions. *A* is the wheel, *B* the driving-pulley, *C* the inlet-pipe, *D* the outlet-pipe or nozzle, and *E* the shut-off valve, shown on a larger scale at the right. The framework is made of the most substantial character, to avoid vibrations and consequent wear and tear. Hydraulic derricks of the style shown in Fig. 3107 have been designed to remove large bowlders and stones that cannot otherwise be handled. *A* is the hurdy-gurdy water-wheel, *B* the water-pipe, *C* the drum, *D* the rope, and *E* the valve. A decrease in the speed of the rope, with a resulting increase in power, is effected through a single set of intermediate gearing. The German hydraulic derrick, Fig. 3108, is arranged for rapid movement from place to place, as it is required for handling materials in various parts of the claim. This derrick is mounted upon a globe *C*, out of which projects a pipe *J*, which furnishes the means of discharging the water upon the blades of the wheel *I*. The mast *A*, drum *D*, and wheel *I* are supported upon the globe *C*, and revolve with it. The globe receives its supply of water through the pipe *G*.

While the first ten years of hydraulic mining in California were largely devoted to laborious and costly experiments without satisfactory returns, the work of later years has proved very remunerative, and established the fact beyond a possibility of doubt that the great bulk of precious metal still remains in these old river-channels, only awaiting the advent of energy, enterprise, and capital to be uncovered, separated, and made available for use. The financial importance of this industry will be recognized at a glance, when it is recalled to mind that the annual product of the gravel-mining in California is double if not treble that derived from the quartz, and that during the uncommonly dry season of 1877 this State produced from hydraulic mining alone about $7,000,000.

We are indebted to Aug. J. Bowie, Jr., E. M., Hamilton Smith, Jr., C. E., Thomas Egleston, Ph. D., and Hermann Schuesler, C. E., for their kindly assistance and the use of their notes and corrections in the preparation of this article.

F. H. McD.

MITRAILLEUSE. See Ordnance—Machine Guns.
MITRE-BOX. See Saws.
MOMENTUM. See Dynamics.
MORTAR. See Concretes and Cements, and Ordnance.

MORTISING AND TENONING MACHINES. *Mortising Machines.*—The power mortising machine forms an exception among wood-working tools, as it is the only machine that performs its work by positive and intermittent blows. In other machines, when the resistance is too great, the belts yield and no damage occurs; but with the mortiser all parts must be so proportioned and constructed as to preclude any possibility of breaking from jar or concussion. The chisel-bar movement is dissimilar in different machines, and they are classed as follows by Messrs. J. A. Fay & Co.:

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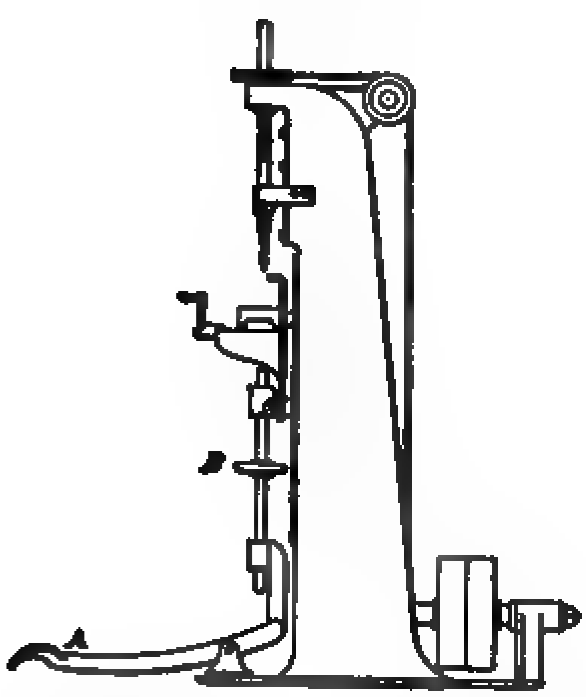
3109.

3110.



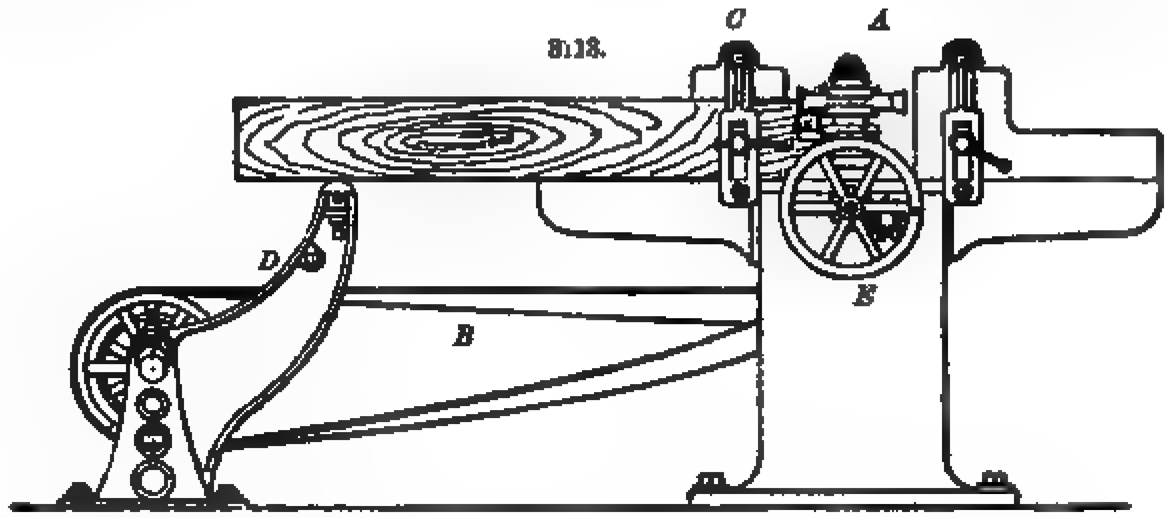
1. Machines having a fixed position of the eccentric-shaft, with a positive and continuous motion of the chisel-bar, where the wood has to be raised or brought to the chisel to receive its action. These machines have a great advantage in the simplicity of their construction and the high speed at which they run, and are well adapted to light work, such as door, sash, blind, and furniture mortising.

2. Machines in which the mortise is formed by a revolving traversing auger or bit, so constructed as to cut on the side as well as on the end. These machines are extensively used for chair and special work, where many pieces are required to be duplicated.

3. Machines in which the eccentric-shaft and the reciprocating parts are all moved to the work. The objection to this class of machine is, that the force of the blow falls equally upon the chisel-bar and the treadle of the operator, except as neutralized by the inertia of the crank-wheel and attachments. This class of machine is best adapted to quick motion and light work, and is unsuited to heavy mortising with slow motion.

4. Machines where the stroke is produced by a variable eccentric, increasing or diminishing the throw of the chisel-bar in both directions. This class requires a stroke twice the depth of the mortise, with the clearance added which gives a long motion to the reciprocating parts. This is apt to limit the speed of the machine and cause unnecessary wear and vibration.

3113.



5. The graduated-stroke mortising machine, where the motion is produced by lengthening the connection from the eccentric to the chisel-bar, starting from a still point.

6. Machines where the chisel-bar has a progressive downward movement to the required depth of mortise, the crank-shaft and guides having a fixed position.

In the mortising machine shown in Figs. 3109 and 3110, which are front and side views, the chisels have a uniform stroke of 5 in. The table with the work thereon is raised by the foot-treadle shown at *A*, its height being regulated by the hand-wheel *B* operating the right- and left-hand screw to which it is attached, one end of the screw acting upon a nut in the upper end of the treadle, and the other end operating a nut attached to the table-guide. The table is adjustable horizontally for mortising at an angle when required. The form of chisel used in this class of mortising machine is shown in Fig. 3111. The spindle carrying the chisel is arranged by suitable mechanical movements to make one quarter turn while reciprocating at the upper end of its movement; thus the cutting edge of the chisel is brought at will to bear upon either side or end of the mortise. To prevent the work from lifting with the up-stroke of the chisel, the guards *G G* are provided.

Fig. 3112 represents a power sash-mortising machine designed by Messrs. J. A. Fay & Co. for sash, blind, and door mortising. It has a novel compound bed, on which the stuff to be worked is clamped and moved under the chisel by a rack and pinion, the treadle raising the bed so that the chisel enters the wood gradually. The tool works in deeper at each stroke until the desired depth is

gained, thus preventing the severe concussion and jar which always occurs when the chisel enters the wood at full depth. The same bed is used for straight mortising in the usual manner, as it is provided with bent stops for holding the stuff, which are arranged to swing and adjust to different heights. The bed is also arranged for radial mortising, and the treadle is contrived so as to produce greater or less throw of the table. The speed of the light and loose pulleys is about 500 revolutions per minute.

TENONING MACHINES.—Fig. 3113 represents a tenoning machine having its cutter at right angles to the work. The revolving cutter *A* is placed upon a vertical spindle driven by the belt *B*. The timber is held by the clamps *C*, and is supported at the outer end by the arm *D*, which carries a roller upon which the timber rests. The cutters are fed across the work by means of the hand-wheel *E*, which by means of screws and gears traverses the spindle carrying the cutters in a straight line, the angle of the tenon cut depending upon the angle at which the work is set in the machine. It is obvious that, there being a work-holding device or clamp and a table on each side of the cutters, the ends of two separate pieces of work can be operated upon simultaneously. In the engraving the lower cutter is shown removed, but it is obvious that the thickness of tenon cut depends upon the distance between the upper and lower cutters, which is governed by the thickness of washer placed between them.

Fig. 3114 is a patent sash- and door-tenoning machine, in which the heads are single, but so placed on their frames that a tenon can be made double the length of the cutter by passing the stuff through twice. The knives are placed at an angle on the heads, which gives a shearing cutting-edge and produces smooth work. The gateways that carry the cutter-head spindles are gibbed to a vertical slide, and are raised together or separately as may be desired, one screw raising both frames, which governs the thickness of the lower shoulder. The other screw separates the heads and regulates the thickness of the tenon. The screws are furnished with locking devices to prevent any vibration. The machine is made with one or two coping-heads, or without any. The cope-heads have independent adjustment, and are attached to the cutter-head frames. The countershaft pulleys make about 950 revolutions per minute.

MOTION, LAWS OF. See DYNAMICS.

MOULDING is the art of producing the forms or moulds in which metal is cast to a desired shape. (See also CASTING.) It may be divided into two classes, namely, green- and dry-sand moulding, and loam moulding. In the first class, patterns of the articles wanted are universally employed in forming the mould; in the second division, the ordinary patterns are dispensed with, heavy castings of a regular form, such as sugar-pans, gas-retorts, etc., being produced.

MATERIALS AND TOOLS.—The principal materials used in the various branches of moulding are sand of various kinds, clay, blackening, coal-dust, and cow-hair.

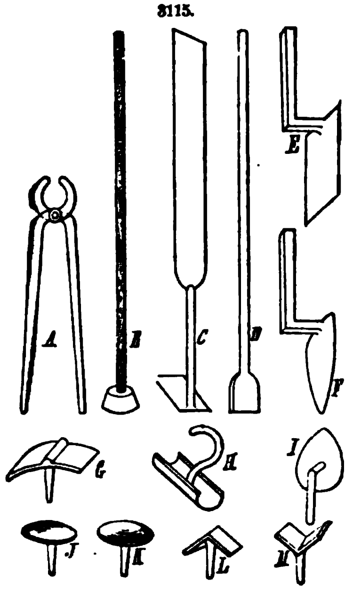
Sand is generally the best material for forming moulds, as the hot iron has no chemical action upon it; it behaves well as a conducting medium for the air expelled from the space by the metal, and for the gases generated in the mould; it possesses considerable adhesiveness when rammed together; and it is made to conform very accurately to the surface of the pattern. The principal element of a good sand should be silica, with a little magnesia and alumina. Parting-sand should be of a lighter color than the moulding-sand, and should be clean, fine-grained, and of uniform texture, free from salt and chalky matters. Red-brick dust, fresh free sand, or blast-furnace cinder may be used; but in any case the substance employed must be one which does not retain moisture. Green-sand moulds are faced with oak-charcoal dust ground to an impalpable powder. Dry-sand or loam moulds are faced with wood-charcoal dust ground to powder, or with a black wash consisting of coal-dust mixed with water. Moulding-sand is always mixed damp with about 1 part of coal or charcoal dust to from 10 to 15 parts of sand. In facing-sands the proportion of coal-dust varies from 1 in 10 to 1 in 20. The use of the coal-dust is to supply a binding but porous material, which shall be of service when the sand and clay of the mould shall have been intensely heated and perfectly desiccated by the flowing metal. Many other substances have been proposed and tried, but no one of them has proved to be superior to coal-dust.

Loam as a material for moulds is next in value to sand. It is clay, either calcareous or ferruginous, containing a considerable quantity of sand. Pyrites and flinty pebbles are objectionable in it, and the presence of more than 5 per cent. of carbonate of lime should determine its rejection. Loam is ground in suitable mills; and in order to give the necessary porosity to such portion as is used for the body of the moulds, powdered coal and coke, horse-dung, straw, chaff, ox-hair, bran, or chopped tow may be added.

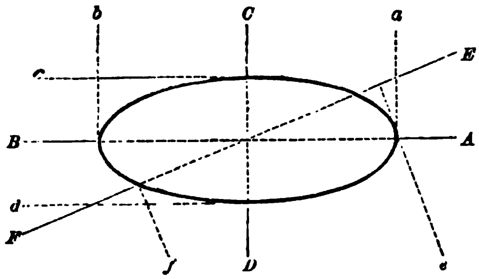
Moulders' Tools.—In Fig. 3115 are represented the different kinds of tools used by moulders. *E* is the trowel, the instrument in most frequent use. There are various sizes of it, from one-fourth to 2 in. broad in the blade, and 3 in. long generally. The purpose of the trowel is to clean away and smooth down the surface of the sand, to press down and polish the blackening, repair injured parts of the moulding, and so on. *F* is another form of trowel, of a heart shape. It is particularly employed for entering acute angles in a moulding, into which the square trowel evidently cannot go. *H* is another form of tool for managing hollow impressions in the sand. *C* is the form of the sleeker and cleaner. As the trowel is applicable only to open, plain surfaces, this tool is used for cleaning and smoothing sunk surfaces in the sand which the ordinary trowel cannot reach, as the impression of a flange, or of any flat part of a pattern presented edgewise to the sand. The upper end is applied to the sides of such an impression for sleeking or smoothing it, and the under end goes to the bottom where it is used both for taking up loose sand lying there, and for pressing and smoothing down the surface. It is to be noticed, too, that the upper end is presented edgewise to the direction of the spade at the under end, so that when this is employed at the bottom of a deep recess, the upper end stands sidewise to the sides of the recess, and permits free motion. *D* is the first rammer; it is about 4 ft. 6 in. long, and its under face is about 2 in. by 1 in. Sometimes the upper end, by being

tapered off, is made to serve for forcing holes in the sand. *B* is the second rammer for finishing the work of the first. It is round in the face, about 3¼ in. diameter, with a wooden shank of convenient length. *A* represents the pincers used for laying hold of and shifting about the castings. *G* to *M* represent the forms of the cast-iron sleekers employed in the operations of hollow moulding. *J* and *K* are convex and concave sleekers for corresponding surfaces. *L* and *M* are tools with double plane surfaces at certain angles to each other. Of these there are a variety having their planes at different angles to suit the various salient and retreating angles that occur in mouldings. *G* is a sleeker for the impressions of beads, and *I* serves to smooth flat surfaces generally. Besides these tools, shovels are used for working the sand, sieves and riddles for refining it, and bellows for blowing off loose sand from the mouldings; pots for holding the parting-sand and the water used, swabs for applying the water, and bags for blackening. There are also piercers and prickers, as they are termed, being pieces of thick iron wire, sharpened at one end to a point, for piercing the sand to let off air.

3115.



3116.



In sand-moulding, where but few articles are to be produced from the mould, a wooden pattern suffices; but as such patterns become distorted by warping, metal ones are preferably employed. In order to make a metal pattern, however, a preliminary one of wood is required; and the manner in which this pattern is put together determines the manner in which the mould is to be made. Hence the operations of the pattern-maker control to a great extent those of the moulder. Whenever practicable, the pattern is so formed as to enable its moulding to be performed by a mould parted in one place only. Examples of patterns which will illustrate the general principles of pattern-making are given further on.

The explanatory diagram, Fig. 3116, will elucidate the principles concerned in the construction of the pattern to provide for its extraction from the mould. The figure to be moulded is supposed to be a rod of elliptical section, the mould for which might be divided into two parts through the line *A B*, because no part of the figure projects beyond the lines *a b*, drawn from the margin of the model at right angles to the line of division, and in which direction the half of the mould would be removed or *lifted;* the model could be afterward drawn out from the second half of the mould in a similar manner. The mould could be also parted upon the line *C D*, because in that direction likewise no part of the model extends beyond the lines *c d*, which show the direction in which the mould would be then lifted. The mould, however complex, could be also parted either upon *A B* or *C D*, provided no part of the model outstepped the rectangle formed by the dotted lines *b c*, or was undercut. But, considering Fig. 3116 to be turned bottom upward, and with the line *E F* horizontal, the removal of the entire half of the mould upon the lines *e f* would be impossible, because in raising the mould perpendicularly to *E F*, that portion of the mould situated within the one perpendicular *e* would catch against the overhanging part of the oval toward *A*. Were the mould of metal, and therefore rigid, it would be entirely locked fast, or it would not "deliver;" were the mould of sand, and therefore yielding, it would break and leave behind that part between *A* and *E* which caused the obstruction. Consequently, in such a case, the mould would be made with a small loose part between *A* and *E*, so that when the principal portion, from *A* to *F*, had been lifted perpendicularly or in the direction of the line *e*, the small undercut piece *A* to *E* might be withdrawn sidewise, on which account it would be designated by the iron-founder a *drawback*, by the brass-founder a *false core.*

The moulds for small castings are made in frames termed flasks, and these are further designated by the number of parts of which the flask is composed. Thus, when there is but one parting to the mould, the flask, being composed of two halves, is termed a two-part flask, and so on. In Fig. 3117 is shown a two-part flask, the upper portion of which, *C*, is termed the *cope*, and the lower, *N*, the nowel. To hold the sand in the flask, cross-bars are employed, which are fixed to the flask so as to leave a thickness of an inch or two of sand all around the surface of the pattern. In Fig. 3118 is shown a pattern composed of two halves and to be moulded in a two-part flask, the vertical line *A A* showing the division of the pattern.

The method of moulding is as follows: In Fig. 3119, *N* is the nowel, placed upon a piece of board *B* which rests upon the floor (or upon a bench if the work is very small). One half of the pattern *P* is placed upon the board, and the flask is filled with sand. The sand is at first sifted

through a sieve to eliminate any foreign substances and insure having fine sand around the pattern, so as to obtain a smooth casting. As the filling proceeds, the sand is tightly rammed around the pattern, and finally it is leveled off even with the top of the flask. The latter is then turned upside down, and the top half of the pattern is placed upon that already in the nowel. Two dowels are provided to insure that the two half patterns shall coincide all around their edges. The cope is then placed upon the nowel, and to maintain it in its proper position and enable its removal and reinstatement in the same place, it is provided with two pins on one side and one on the other, the nowel having lugs containing holes to receive the pins as shown in Fig. 3120. The top flask is then

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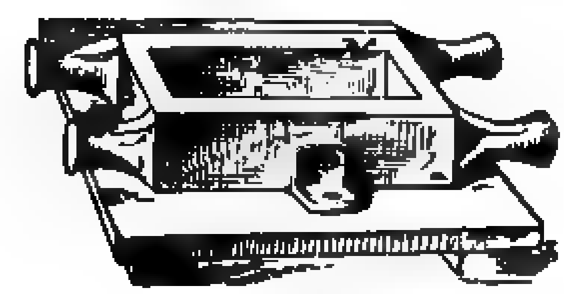
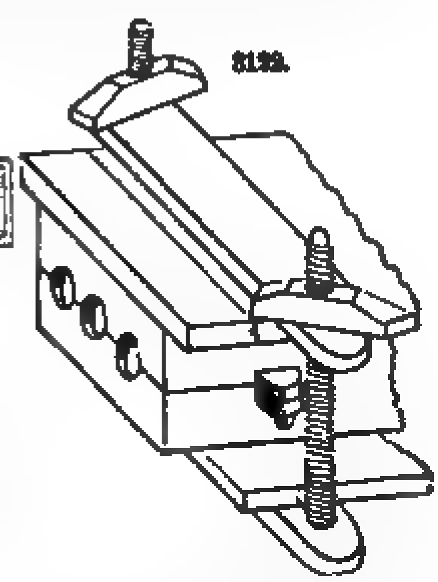


3118.

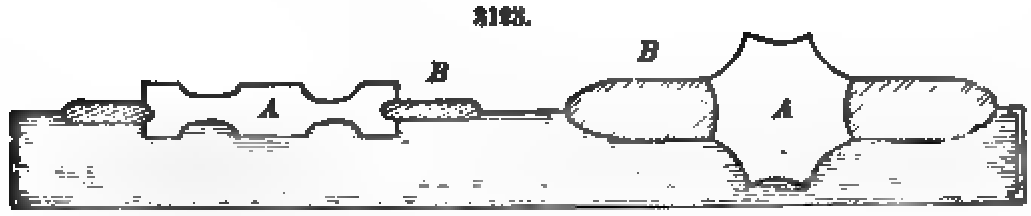
similarly filled with rammed sand, the finished mould appearing as shown in Fig. 3120, in which *P P* are the two halves of the pattern, *N* the nowel, and *C* the cope. *R* is the gate or hole through which the melted metal is poured. It is made either by forcing a thin tube through the cope, or else by inserting in the cope before filling it with sand a wooden pin, the extraction of which after the cope is filled leaves the gate. To enable the gases which are generated by the melted metal to escape gradually without causing an explosion, the sand is pierced by a piece of fine iron wire, leaving numerous vents which are too fine to permit the melted metal to enter them, and yet are sufficiently large to afford vent, as it is termed, to the mould. The cope is taken off to extract the pattern, one

3121.

3122.



3123.



half of the latter lifting with the cope, while the other half remains in the nowel. To loosen the pattern in the mould, so that it shall not lift the sand when drawn therefrom, a piece of pointed iron wire is lightly driven into the pattern and tapped laterally in two or more directions. Hence the mould is always larger than the pattern from which it was formed. This, however, is offset to some extent in small castings by the contraction of the metal while passing from the fluid to the solid state. It is found in practice that in castings of about 4 in. section the loosening of the pattern in the mould is about the same in amount as the shrinkage of the metal while cooling; hence, as the size of the pattern decreases the casting will be larger, and as it increases it will be smaller, than the pattern. In moulding very small patterns it is not necessary that the patterns be made in two halves,

although they may be moulded in a two-part flask. Thus all the patterns in Fig. 3121 could be made in one piece and pressed half-way into the sand of the nowel, as shown. After a pattern is moulded complete, it is necessary, previous to pouring the metal, either to place weights upon the cope, or else, as in the case of small flasks, to clamp them together as shown in Fig. 3122; otherwise the gases generated by the fluid metal will cause the cope to lift, and the metal will flow out through the parting of the mould.

Cores are bodies of sand placed in the mould to serve as a part of the pattern, and in many cases to enable the pattern to be cast in a two-part flask, where a three- or four-part one would otherwise be requisite. Thus, in Fig. 3123, *A A* are patterns and *B B* the respective cores. The patterns in this case would be made of the forms and sizes of *A* and *B* respectively, *B* being in each case removable from *A*. The patterns would be moulded irrespective of the cores, and the latter would be placed in the completed mould after the patterns were extracted. The cores themselves are made in a separate mould termed a core-box, which is usually composed of two halves to admit of the extraction of the core. Fig. 3124 shows the halves of a cylindrical core-box, *C* representing the core.

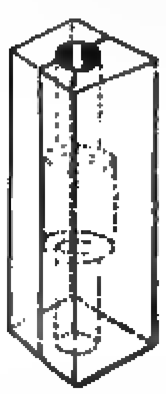
From the weakness of cores they are usually taken from the box in the position in which they

3124. 3125.

will lie. Thus, in Fig. 3125, the core *C* would be laid flat on an iron plate and the sides of the box removed. If the cores are so slight as to render it necessary, pieces of iron are inserted in the core-box to strengthen them; and in any event they are dried in an oven, which adds considerably to their strength, especially when flour or some similar substance is mixed with the loam, as is the case in small cores.

Some core-boxes are made like Fig. 3126, for cylindrical cores; these divide through the axis, and are kept in position by pins; at the time when they are rammed they are fixed together by wood or iron staples, embracing three sides of the mould, or else by screw-clamps. For straight cores, say 1 in. wide, 12 in. long, and half an inch thick, the pieces of wood, Fig. 3127, are also 1 in. thick, with an opening between them 12 in. long and half an inch wide. This core-box is laid on a flat board; it is also held together with clamps, but without pins in the core-box, as the projection at the one end gives the position; it is rammed flush with both sides, and the two parts can be then separated obliquely. If it is preferred to make the cores to the precise lengths instead of cutting them off, this core-box admits of contraction in length, in the manner of a type-mould; and by placing thin slips between the two halves it may be temporarily increased in width, but not in thickness. Fig. 3128

3126.



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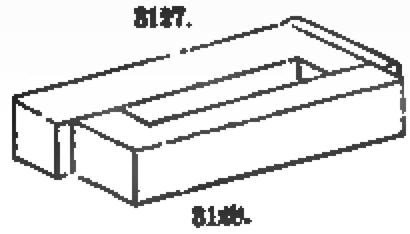
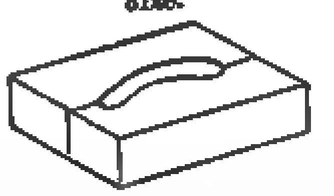


3128.



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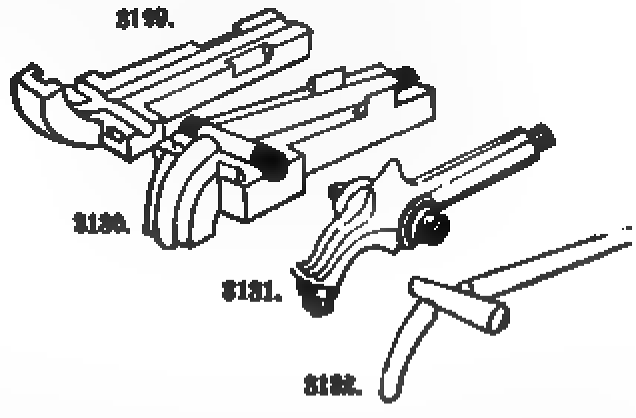


3130. 3131. 3132.

is a similar core-box for a casting with circular mortises; this requires either pins or projections at each end, as it cannot be opened obliquely. Core-boxes are sometimes made of plaster of Paris; wood is much better, and metal the best of all.

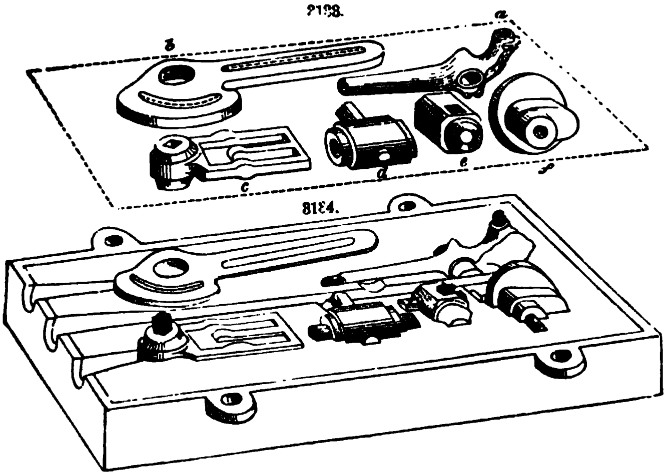
Many works require core-boxes to be made expressly for them; thus the dotted line in Fig. 3126 shows an enlargement in the centre for coring a hole of that particular section. Figs. 3129 and 3130 represent the two halves of a brass or lead core-box suitable to the stop-cock, Fig. 3131; and Fig. 3132 shows the core itself after its removal from the part of Fig. 3130 in which it is also figured. In Fig. 3131, the model from which the object is moulded, the shaded parts represent the projections or *core-prints*, which imprint within the mould the places where the extremities of the core, Fig. 3132, are supported when placed therein.

The various kinds of core-boxes are rammed full of new sand, sometimes with extra loam; the long cores are strengthened by wires; they are carefully removed from the boxes, and thoroughly dried before use, in the oven prepared for the purpose. Others prefer sand, horse-dung, and a very little loam, for making cores; these are dried and then well burned, for which purpose they are put into an empty crucible within the fire, the last thing at night, and allowed to remain until the morn-

ing. This consumes the small particles of straw, and renders them more porous, in consequence of which the works become sounder from the free escape of air, which cannot be too much insisted upon.

Fig. 3133 represents several examples of coring. In this view the works are represented of their ultimate forms, that is, with the holes in them. In Fig. 3134, the models are arranged in the flask, with the runners all prepared, the prints of the cores being in every case shaded for distinction. Thus *a* is the stop-cock, of which explanation has been already given. *b* has a straight and a circular mortise; this pattern *delivers its own core*, as the model is made with mortises like the finished

3133.



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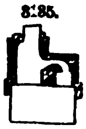
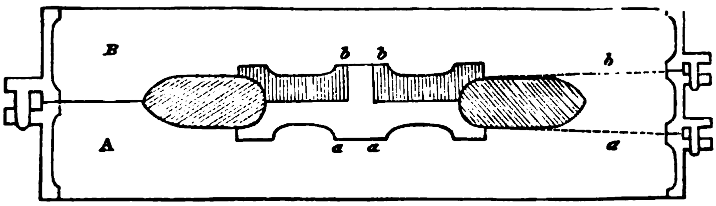


work. *c* only requires a perpendicular square core; *d* a round core parallel with the face of the flask, and in this manner all tubes and sockets are cast, whether of uniform or irregular bore (see Fig. 3126). *e* has two rectangular cores crossing each other at right angles; and *f* is the cap of a double-acting pump, the core for which is shown in section by the white part of Fig. 3135, the shaded portions being the metal. The great aperture leads to the piston, and the two smaller are for valves opening inward and outward; this of course requires a metal core-box capable of division in two parts, and made exactly to the particular form.

In addition to the cores used for making holes and mortises, much ingenious contrivance is displayed in the cores employed for other works of every-day occurrence, the undercut parts of which would retain them in the sand but for the employment of these and analogous contrivances. It will now be readily understood that if, in Fig. 3123, the parts shaded obliquely were separate, there would be no difficulty in removing first the upper half of the flask, then the false cores, after which the patterns would be quite free. By such a method, however, the circular edge of a sheave would require at least three such pieces; but Fig. 3136 shows a different way of accomplishing the same

3136.



thing, when the pattern is made in two parts in the manner represented. The entire model is first knocked into the side *A*, the sand is cut away to the inner margin of the pattern, which terminates upon the dotted line *a*, and the side *A* of the mould is then well dusted; a layer of sand is now thrown on, and rammed tolerably firm to form an annular core, which is made exactly level with the inner margin *b* of the pattern, and the core is well dusted; lastly, the side *B* is put on and rammed as usual. To extract the model, the side *B* is first lifted, the half pattern *b b* (which is shaded) is removed, and the ingate is cut in the side *B* to the edge of the pulley; the mould is well dusted with flour and replaced. The entire mould is now turned over. *A* is first removed, then the remaining half pattern *a a*, which must be touched very tenderly or it will break down the core; and the runner (which divides in two branches around the core) is also scooped out in the side *A*, which is dusted with flour and replaced, ready for pouring. Common patterns not requiring cores are frequently divided into two parts in the above manner, so that when the mould is opened the pattern may divide and remain half in each side; this lessens the risk of breaking down the mould and the attendant trouble of afterward repairing it.

The cores for long pipes and similar objects are made as shown in Figs. 3137 and 3138. A piece of board *B* is made with one edge formed to suit the shape of core required; an iron bar *D* is

mounted on two trestles A A, and a crank-handle is affixed at one end of D, which is revolved, and a twisted straw rope is wound around it from end to end. The rope is then covered with a mixture of loam and horse-dung, which is swept into cylindrical form by the edge of the board B, which is held to the trestles by weights or their equivalents. The core proper has thus a straw core, through which the gases generated in the mould by the fluid metal may pass freely off. In some cases the cores themselves are made in halves and placed together after being dried. An example of this is shown in Fig. 3139, which is a core for a faucet-cock, the line of division being denoted by A B C D. Fig. 3140 shows an example of the use of a core to enable the pattern to be cast in a two-part flask. The pieces A B (which could not otherwise be extracted from the mould) are attached to

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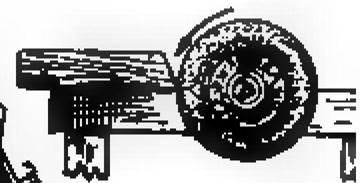

3139.

the body of the pattern by the wire shown at A. C is a core-print—that is, a piece of wood forming a part of the pattern, but not to be found in the casting, being provided to form a recess in the mould into which the core itself can be laid, and by which it can be supported in the mould. In this case the moulder would withdraw the wire pin after having rammed the sand around the lower part of the pattern. Hence, when the body of the pattern is withdrawn the pieces A and B are left in the mould, and must be extracted laterally afterward.

Cores are sometimes swept up as shown in Figs. 3141 and 3142, which represent a half core for a

3140.

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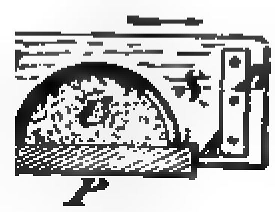
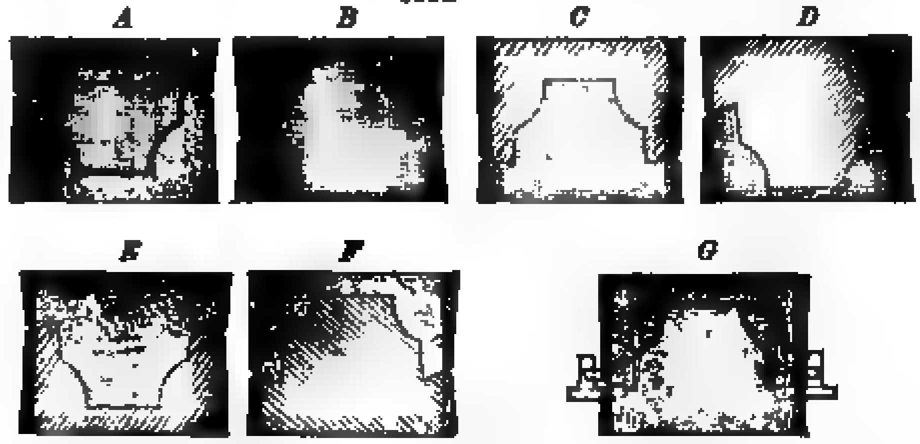
3142.



pipe-bend. An iron plate P, having its edge trimmed to the shape of the required core, is provided, upon which the core in separate halves is made and dried. C represents the core, and S a piece of wood termed the "strike," strengthened by the battens or plates B B. The edge of the semicircle of the strike is leveled off as shown. The core-maker places upon the iron plate sufficient material to form the core, and, placing the strike against the edge of the plate, sweeps it along that edge. The semicircle of the sweep leaves the core upon the plate while removing off the surplus material.

3143.

3144.



Moulds for Chilled Castings.—Chilled rollers are the most important examples of chilled castings. The mould for a chilled roller consists of three parts, as shown in Fig. 3143. The lower box of iron or wood is filled with "new sand," or a strong composition of clay and sand, in which a wood pattern is moulded, which forms the coupling and the neck of the roller. The middle part of the mould is the chill, a heavy iron cylinder well bored. The upper part of the mould again consists of

a box, but is higher than the lower box, so as to make room for the head in which the impurities of the iron (*sullage*) are to be gathered. The two boxes with their contents of sand must be well dried. In some establishments the two ends of the roller are moulded in loam over the chill, to secure concentricity of roller and coupling; but this can be quite as safely arrived at by fitting the ears and pins of the boxes well to the chill. The chill is the important part in this mould: it ought to be at least three times as heavy as the roller which is to be cast in it, and provided with wrought-iron hoops to prevent its falling to pieces, for it will certainly crack if not made of very strong cast iron. The iron of which a chill is cast is to be strong, fine-grained, and not too gray. Gray iron is too bad a conductor of heat; it is liable to melt with the cast. Iron that makes a good roller will make a good chill. The face of the mould is blackened like any other mould, but the blackening must be stronger than in other cases, to resist more the abrasive motion of the fluid metal. The chill is blackened with a thin coating of very fine black lead, mixed with the purest kind of clay; this coating must be very thin, or it will scale off before it is of service.

Jobson's System of Hollow Moulding.—A great improvement was effected in this class of moulding by the arrangements introduced and employed by R. Jobson, especially where a large number of castings are required from one pattern. In Mr. Jobson's process of moulding, after the pattern has been first partially imbedded in the sand of the bottom box as in ordinary moulding, *A*, Fig. 3144, and the parting surface has been accurately formed, the top box is placed on, and is filled with plaster of Paris or other similar material, to which the pattern itself adheres. When the plaster is set, the boxes are turned over, the sand is carefully taken out of the bottom box, and a similar process repeated with it, as in *B*, using clay-wash to prevent the two plasters from adhering; this forms a corresponding plaster mould of the lower portion of the pattern. These two plaster moulds may be called the "waste blocks," as they are not used in producing the moulds for casting, but are subsequently destroyed. Reversed moulds in plaster, *C* and *D*, are now made from these waste blocks, the pattern being first removed, by placing upon the bottom box a second top box, an exact duplicate of the former top box, and filling it up with plaster, having used clay-wash as before, and doing the same with the other box. Reversed moulds are thus obtained, from which the final sand-moulds for casting are made, by using them as "ramming blocks," upon which the sand forming the mould is rammed by placing a third duplicate top box, *F*, upon the ramming block, and a corresponding bottom box, *E*, upon the ramming block. The requisite gits, or gates, runners and risers, are formed previously in the original sand-mould, and are consequently represented in the ramming blocks, *D* and *E*, by corresponding projections or ribs upon the parting face of the one and hollows in the other, which are then stopped up with plaster, and these are properly repeated in the final sand-mould, *E* and *F*; these last therefore, when put together, form a complete mould for casting, just like an ordinary sand-mould, *G*.

Loam-Moulding.—In the casting of metals, especially those having high melting-points, there is always more or less production of gases, together with expansion of air; and if the operation were performed in a mould which was not porous, the bubbles would mar the surface of the casting as well as enter to a certain extent into its interior. It is therefore necessary that the mould should possess sufficient porosity to allow of the escape of aëriform matter. Moisture in a mould is only admissible in small castings which cool quickly. Used for large masses of molten iron, the amount of steam formed, together with the expanding gas, would not only endanger the mould, but also the workmen. Dry moulds made of loam are consequently used in heavy castings, partly for the above reasons, and partly because sand could not be properly manipulated or retained in place in large and massive castings. The casting of large cylinders, bed-plates, and condensers for steamships is a very intricate process, requiring good engineering abilities, skill in draughting, and experience in the designer as well as in those who execute the work. The moulds are usually worked from drawings instead of being formed upon patterns. A single piece of machinery is often complex in form, and as the art of the moulder consists in forming a hollow cavity where the carpenter or cabinet-maker would make a solid body, it must be seen that he has a much more difficult task before him; for he has not only to form an inside structure similar to the future cast, but an outside one of a reverse form as well, and these two forms must be perfectly related to each other. He has also to provide channels and gateways for the pouring of the metal, and they must be so arranged as to secure its perfect flowing to every part, and as nearly as possible its simultaneous cooling. Allowance must also be made for shrinkage, and an almost infinite number of precautions, suited to particular exigencies as they arise, must be observed. The draughting requires great forethought and calculation, and the execution not only involves a perfect comprehension of the plan, but a constant vigilance in avoiding errors and causes of miscarriage. A description of the moulding and casting of a complex piece of machinery would require a very great detail of explanation and numerous illustrations, and then could not be comprehended except by repeated visits to the foundry. The moulding and casting of a simple cylinder will therefore be taken.

A loam-mould, secured in a pit, and ready for casting, is represented in Fig. 3145. *a* is a hollow mould surrounding the core, and surrounded by the cope; *b*, hollow inside of core; *c c*, bolts holding cope together; *d*, air-tube for discharging air from core; *e e*, air-tubes; *f f*, pouring-holes. It is constructed in the following manner. An iron foundation-plate is laid upon the floor of the foundry, and leveled. An iron ring, flat and of a breadth equal to the thickness of the walls of the core which is to be built upon it, and of a diameter equal to that of the inside of the future cylinder, is laid down, and the core is built upon it to the height desired. An apparatus for describing and sweeping the surface of the core is now erected, which is called a sweep, and consists of a spindle and templet, represented in Fig. 3146. An arm *a*, supported by some portion of the building, holds the upper end of the spindle *b*, while the lower end turns in a hole in the centre of the foundation-plate. A collar, *c*, which may be adjusted at any required height, is provided with an arm, to which again the templet *d* is firmly held by means of a mortise, which slides over the arm, and may be set at any

desired distance from the spindle. From the construction of the machine it will be perceived that it may be used to describe either the inner or outer surface of a cylinder; therefore it serves to give form both to the surface of the core and to the inner surface of the cope. After the sweep is placed in position, the core is commenced by building up a cylinder of brickwork upon the circular plate, its dimensions being governed by the templet, which in sweeping about its axis should leave a small space between itself and the bricks to allow of finishing with loam. The bricks are laid up in loam, and the same material is laid upon the surface until it has sufficient thickness to be scraped off by the templet, as shown in Fig. 3146. The top of the core may be swept and leveled by the arm, the templet being removed. If the cylinder is to be cast with a bottom, an iron plate is fitted to the

3145.

3146.

upper end of the core, and a proper thickness of loam laid upon it. This may be built upon the core, or it may be done separately, and the parts put together after they are dried. When the core is finished it is lifted by a crane, by means of chains or rods attached to the circular plate upon which it rests, upon a car which passes on a track to one of the drying ovens represented in Fig. 3147. The templet is then placed at that distance from the spindle by which it will describe the inner cylindrical surface of the cope, which is built up with brickwork and loam in a similar manner to that used for the core, except that for convenience it is usually built in two sections (see Fig. 3148). Iron rods are laid in the brickwork, passing from top to bottom, and securely fastened to the bottom plate. A cap is then made by fitting an iron plate to the top, adding brick and loam, and securing it by the rods which pass through the walls from the bottom plate. When finished, all these parts

3147.

3148.

are washed with a mixture of charcoal or plumbago dust and water, the mixture being sometimes applied two or three times. A strong cross-piece of iron is then fastened to the top of the cope, hoisted by means of a crane upon the carriage, and taken to the oven.

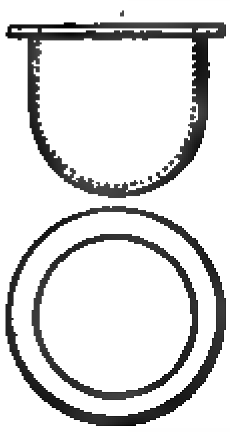
After both core and cope have been thoroughly dried, they are lowered into a pit formed in the floor of the furnace. Upon the bottom of this pit there is an iron foundation upon which the cope and the core both rest, and to which they are properly adjusted and secured. Care has been taken to provide the cope with the necessary holes for pouring and for the discharge of air. Sand is then thrown into the pit about the sides of the mould, and well tamped down to prevent any spreading during the casting. The relation of the parts is represented in Fig. 3145. A powerful expansive

force is applied to the interior of the mould when the hot metal is poured in, and the greatest precautions must be taken to have all the iron fastenings as well as the sand tampings strong enough to withstand the pressure. Into the holes intended for the escape of air iron tubes are placed, of sufficient length to reach above a layer of loam which is now laid over the cope. Into the holes for pouring plugs are placed and the loam formed around them in cups, which are connected with channels through which the metal runs in pouring. In the figure a tube is seen leading a few inches downward from the lower part of the hollow of the core, then horizontally beyond the edge of the mould, and thence up to the surface of the foundry floor This is for the purpose of carrying off gaseous products from the core. In casting a cylinder without a bottom, it will only be necessary to have a tube extended directly upward to the surface. The securing of the mould for the cylinder of a large steam-engine is a matter which requires the greatest vigilance. The pit into which it is lowered must be dry, and is generally built like a cistern and bricked and cemented on the sides and bottom; and care must be taken to keep the mould dry till the casting is done. The cope must be well bolted to the bars that come through the sides from the bottom. A rim of iron plating may be placed around the part that projects above the ground, reaching high enough above the top of the cope to hold a layer of sand. A heavy iron cross is then raised over the mould and fastened with bolts, by which and also by its weight it aids in sustaining the strain at the time of casting. This is called packing. Fig. 3149 represents the packing of a mould for a large cylinder.

3149

Sweep-moulding for small work is illustrated in Figs. 3150 to 3158. Let it be required to produce a casting such as is shown in Fig. 3150, a sort of pan or boiler, often used. Fig. 3153 is a sectional view of the mould complete; it is formed of two parts, the lower being called the "seat" and the upper the "cope." Figs. 3153 and 3154 illustrate the method of forming each of these parts. The

3150.

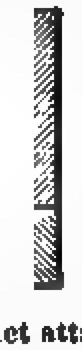


3151.

3152.

material used by the founder is called loam, a clayey, plastic composition, very soft. After a certain quantity of this material has been piled up, the sweep is revolved; it shears down the high places and indicates the holes or hollows. Into the latter more material is placed, and the sweep is passed round again, and so on until the job is perfected. It will be noticed in Fig. 3153 that the two parts of the mould are retained in their proper position by a projection on one fitting into a recess in the other; this is the seat proper, and is indicated throughout by *S S*. The pattern-maker's part is to form the sweeps, which he does in the following manner: On a piece of board of the proper thickness for a sweep, the size of which depends on the size of the work, he draws an outline of the job, interior and exterior, from the centre outward; and beyond this he lays off his seat, as shown at Fig. 3152, the dotted lines representing the interior of the piece. He has then simply to cut away to the interior line, and also the step at *S*, and one board is finished, unless he knows the diameter of the spindle and the position of the holes in the carrying bracket attached thereto, in which case he is supposed to cut off, parallel with the centre-line, a portion equal to the radius of the spindle, as a recess for the hub of the bracket *B*, and to bore the holes for the bolts. The board, Fig. 3151, when reversed, should fit that in Fig. 3152 at the lower part, and be of a shape to coincide with the dotted line. Its length must be enough to extend to the centre, minus the radius of the spindle, as shown in Fig. 3151.

3153.

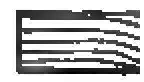


It will be seen by the lines showing the grain of the wood that the board in Fig. 3151 is formed of two pieces, lapped at the corner to give strength; and to avoid too much cross grain, battens may be added

when it is thought necessary. In striking up cores with a horizontal spindle, the working-edge of the board should be beveled; and it is hardly necessary to say that the same is applicable in this case. *P P*, Fig. 3151, is a circular plate of cast iron, used to support the mould while soft; it is not shown in Fig. 3152. By the same method, only varying the outline of the sweeps, a large class of circular work

3154. 3155. 3157.

3156



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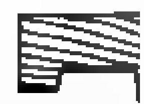


may be produced, including vases, speed-cones, etc. Sometimes it is necessary to cast brackets, pipes, or other projections upon the main piece; to do this, patterns must be made of those projections, and as many patterns as there are projections. The height at which it is required to bed in these brackets, etc., must be indicated to the moulder by a small V cut into the sweep; this will produce, as the sweep revolves, a line upon the mould. For the rest, unless simple directions can be given, the pattern-maker usually visits the foundry, and assists in placing, or at least in verifying the position of the pieces. When the mould is sufficiently hard, and before it is baked, these patterns are withdrawn.

A good illustration of the manner in which moulds may be used in conjunction with sweeps is furnished in the ordinary engine-cylinder. Fig. 3154 is a sectional elevation of a complete mould. Fig. 3155 is a horizontal section of the same, on the line *A B*, showing the outlet for the exhaust-steam. This mould is composed of four parts that are swept or struck up, namely, *S S* the seat, *A B* the body, *C C* the cope, and *M* the main core. The latter may be struck up on a horizontal arbor or formed in a box. In addition to the parts above enumerated are the two steam-port cores and the exhaust-port core, all formed in core-boxes. The procedure is as follows: With a board, shown in Fig. 3156, the seat *S S* is struck up; upon this when dried is placed a flange of wood. It is set centrally; the seat is also carefully beveled and set by the spindle. A pattern of the slide-face, with the parts in which the steam and exhaust passages occur, is set in position on this flange; the top flange of wood is now added, and temporarily fixed to the slide-face pattern, and shored up on the opposite side, so as to maintain it true and level. With the board, Fig. 3157, is formed the body, *A B*. The shape of the exterior of the mould is not important; it is left rough, but some mark must be made, so as to be able, after removing it from the seat, to restore it to the position as before. When the body has dried sufficiently, the pattern flanges and slide-face are withdrawn, the body being lifted from the seat for this purpose by means of bolts passing through it, and terminating in a cast annular plate at the bottom. The projecting flanges on the slide-face are attached by wires or dovetails; otherwise the piece would be locked in the mould. The side-print for the exhaust-port is attached also by a loose wire. Fig. 3158 is a board for sweeping up the cope, *C C*. The whole of these boards are represented as carried to the centre of the spindle; allowance must therefore be made for the spindle and bracket. For very large cylinders, wood flanges are not used, the sweeps being made to a shape to perform the whole of the work.

3159.

MOULD-MAKING MACHINES.—Fig. 3159 represents Eaves & Broadmeadow's machine for ramming the moulds of small castings. There is a carriage composed of a table *A*, which is supported on segmental arms *B*, the latter resting on ways *C*, attached to the main standard. The segments *B* are connected and travel upon the same arc, so that upon them

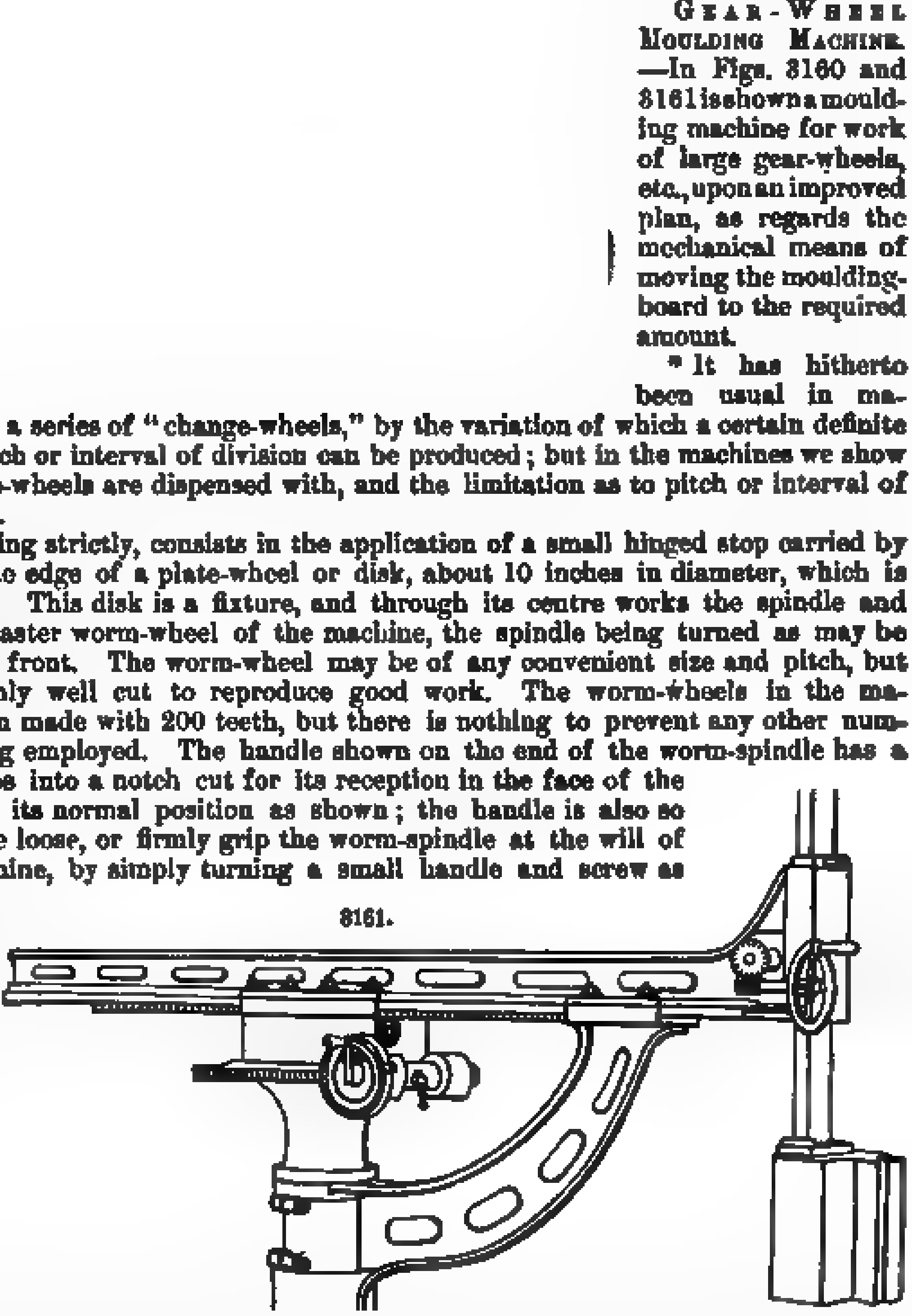
the table can be moved toward or from the workman at will. In the table is an aperture, through which works the rod supporting the platen *D*. The lower end of the rod receives a projection on the vibrating cross-piece *E*. To the latter is attached the operating lever. In moulding, the table is first swung outward by pushing up the lever, and so locked. Then the match and pattern are laid upon the platen, and above the former the lower half of the snap-flask. After the sand is put in, and the receptacle evenly filled, the back-board is laid on top, the table swung in, and the lever pulled down. The back-board is thus brought up against the head-plate, forcing down the loose sand beneath it. The table is again carried outward: on the pressure being relaxed the match is removed, the flask reversed, and the cope adjusted; sand is placed in as before, another board is laid above, and the whole is compressed. Moulds for small objects can be made by this machine in a little over half the time required to produce them by hand; and in general the average saving of labor effected is about 33 per cent.

Gear-Wheel Moulding Machine.—In Figs. 3160 and 3161 is shown a moulding machine for work of large gear-wheels, etc., upon an improved plan, as regards the mechanical means of moving the moulding-board to the required amount.

* It has hitherto been usual in machines of this class to employ a series of "change-wheels," by the variation of which a certain definite number of changes in the pitch or interval of division can be produced; but in the machines we show in our engravings, all change-wheels are dispensed with, and the limitation as to pitch or interval of division is practically infinite.

The invention itself, speaking strictly, consists in the application of a small hinged stop carried by a movable slide placed on the edge of a plate-wheel or disk, about 10 inches in diameter, which is clearly seen in each machine. This disk is a fixture, and through its centre works the spindle and worm which gears into the master worm-wheel of the machine, the spindle being turned as may be needed by the handle seen in front. The worm-wheel may be of any convenient size and pitch, but must of course be thoroughly well cut to reproduce good work. The worm-wheels in the machines we illustrate have been made with 200 teeth, but there is nothing to prevent any other number of primary divisions being employed. The handle shown on the end of the worm-spindle has a spring-catch in it, which slips into a notch cut for its reception in the face of the disk, when the handle is in its normal position as shown; the handle is also so arranged that it can be made loose, or firmly grip the worm-spindle at the will of the operator using the machine, by simply turning a small handle and screw as shown in Fig. 3160, or by the longitudinal movement imparted to the central pin shown in Fig. 3161, in which case the handle is hinged for this purpose at about midway of its length. In each case the effect is the same, and the handle may be made to slip freely on the spindle, or to turn the spindle, as may be desired. It is evident, therefore, that if the handle be made to grip the spindle and one complete turn be given to it, the resulting movement will be that the machine will have been moved in exact accordance with the division of the worm-wheel, or $\frac{1}{200}$ of the circumference of a circle, and would therefore, in a wheel-moulding machine, as Fig. 3160, be suited for making a wheel with 200 teeth. But if a wheel of only 100 teeth were required, it is equally evident that two turns of the handle would produce the required result. But if 201 teeth were needed, or any number greater than 200, the handle must be moved something *less* than one entire revolution; and if less than 200 teeth be required, the handle must make something *more* than one revolution. For properly attaining this purpose, the periphery of the disk is carefully divided into 1,000 parts, which are clearly marked upon it by fine lines.

3161.



The movable slide, with its little hinged stop, can be set to any one of these divisions, or even, if

* *Engineering.*

need be, between any two of them, though such accuracy will be practically unnecessary. Thus, for a division for 100 teeth, the handle must be made to turn the spindle two entire turns, that is, $\frac{200}{100} = 2$; for 150 teeth, $\frac{200}{150} = 1.333$ turns; for, say, 157 teeth, $\frac{200}{157} = 1.2738$ full, or 1.2739 nearly; for 201 teeth, $\frac{200}{201} = 0.995$, the error either way being less than $\frac{1}{200000}$ of the circumference.

But to render this system of measurement, which in itself is not new, practically useful for the purposes named, we find the movable hinged stop and the loose movement of the handle, or the patented portions of the apparatus, applied. Taking the first example (100 teeth), the handle would simply be made to take two turns, that is, from the notch round to the notch twice, to produce the first division. In the second case, the movable slide would have to be "set" with the face of the hinged stop at the division line 333, or at one-third of the way round the disk from the notch; and being thus set, the hinged stop must be turned back out of the way so as to allow the handle to pass it on its first turn, but must be put down so as to stop the handle at that precise point on its second turn. Then the spindle should be fixed in its position by the set-screw seen best in Fig. 3154, while the handle itself is set free from the spindle (as before described) and passed backward from the stop to its normal position. When again tightened on the spindle, and the side set-screw is slackened, the next division can be produced in like manner. In short, the action may be described as consisting of "a turn," or "turns," or "a part of a turn," or "a turn and a part of a turn," or "turns and a part of a turn."

It will easily be understood how this system of subdivision may be carried to any desired degree of exactitude, by the increase of the number of teeth in the master wheel, and by the enlargement of the disk and the increase of the divisions upon its periphery, or, if needed, by the change of the disk into a second master wheel, and the application of the disk to it as before, by means of which the minuteness of the divisions could be carried to any extreme short of infinite. We have made personal examination of some of these machines, and have found them giving great satisfaction both to the owners and to the workmen using them.

The care required in the use of these machines is no greater than that which is necessary in any others of a similar nature. The application of the patented stop, and the loose return-motion of the turning handle, is exceedingly simple. It will have been noticed that one of our examples (201 teeth) is a case of a prime number, the production of which by any combination of change-wheels not having over 201 teeth among them is simply impossible from a master wheel with 200 teeth, except with a partial movement of the handle to some point other than its normal stopping-place, which said point would change and need to be carefully remeasured each time the required movement from tooth to tooth is to be made.

In the new arrangement, however, the measurement is once, and only once, made for each wheel that has to be moulded, and the pitches or divisions that are formed will be absolutely equal from first to last, and any number of divisions may be made from 2 up to 200,000 by the disk as supplied, or to higher numbers if needed, without a single change-wheel. The useful application, therefore, of the invention cannot fail to be appreciated, and should tend to a great extension of the use of wheel-moulding and wheel-cutting machines, and the consequent improvement in all classes of machinery in which toothed wheels are employed.

Statue-Moulding.—The method of proceeding to make a mould for a plaster statue from a clay model is as follows: The model is made pretty wet, so that the moisture from the plaster will not be too much absorbed before it sets. Then a mixture of plaster and water is spread over a certain selected portion of the statue, say the front half of the head and chest, a barrier of clay having been previously erected along the boundary line. After the plaster has set the clay barrier is removed, any injuries that may have happened to the back part of the head and chest are repaired, and the edges of the plaster soaped or washed with a mixture of clay and water. A plaster mixture is then spread over the back of the head and chest, the two applications encasing the whole body above the waist. The remainder of the body may be taken in two or four pieces. If one limb is partially raised or much separated from the other, it may be taken in two halves by itself; but if not, the lower part of the body and both limbs may be moulded in two pieces, one before and one behind. Very often one arm will be taken with the chest, while the other one will be taken separately. After setting, all the pieces may be removed, and of course some of the clay will be brought away with them; but that is of no consequence if the plaster mould is a good one, because, with care, a copy is now secured. After removal, the separate pieces are cleaned with water and the careful use of a brush. The pieces may then be put together and the different parts of the statue cast. Measurements have been taken from certain points on the clay model to the dividing lines, and recorded. These points and lines are reproduced on the plaster casts, so that their edges may be cut to precisely fit each other and preserve the symmetry of the original model. The statue is then completed by putting all the parts together and cementing them with plaster mixture, which is spread on over the seams on the inside by the hand, introduced through an opening made for that purpose, which is afterward repaired in the same way. If a bronze copy is to be taken, and the bronze-founder prefers to have the pieces separate, of course the joining will not be done. In cases where the statue is clad to the throat, there will be one additional piece of work to be performed to prepare it for the bronze-founder, which is to detach the head, and add plaster in a conical form to the neck, which is to be fitted into a collar; for the head should be cast separately in bronze, and the artist should separate it and fit it in its joint himself, so that the proper pose shall be preserved.

A statue in bronze is cast in two or more pieces, generally in from four to six, the number of pieces usually being in inverse proportion to the mechanical and technical skill of the founder. The principal difficulty in casting a statue whole is the cracking and straining of parts on cooling and con-

traction of the metal. If, however, this can be cast very thin, and uniformly so in every part, avoiding masses where there are folds of dress or any irregular surfaces, no cracking may occur. It is not always, however, desirable to avoid division, because the parts may be skillfully joined and much tedious labor saved. In the case of such a work as the statue of Pallas, shown in Fig. 3162, the whole figure, with the exception of the right arm and upper part of the spear, which are to be removed, may be cast in one piece. If of plaster, we will suppose the model to have been varnished with a solution of shellac in alcohol, previous to which it may have been painted with linseed oil and dried, to harden the surface; but this may have been omitted. The statue is laid upon some very fine loam in the iron flask in which it is to be cast, and well adjusted in a bed prepared for it, which fits its surface perfectly, giving a firm support. A quantity of fine loam (which is only to be obtained in a few localities, possessing peculiar physical properties, adhesive and yet porous), after having been ground several times in a mill resembling a sugar-mill, is taken in small portions at a time and pressed and hammered into compact sections upon the surface of the model. Each section must embrace such parts as will allow of its being drawn. The process is similar to that of making a piece-mould with plaster of Paris, except that the material in the latter case is spread on in a plastic condition, while the former is rammed and hammered on. It is a very difficult and tedious one, requiring several weeks and sometimes months to make a mould for a life-size statue. In Germany a composition is used which is spread on like plaster and allowed to harden. Whatever material is employed, the problem is to fit together firm but porous sections over the whole surface, of such forms and dimen-

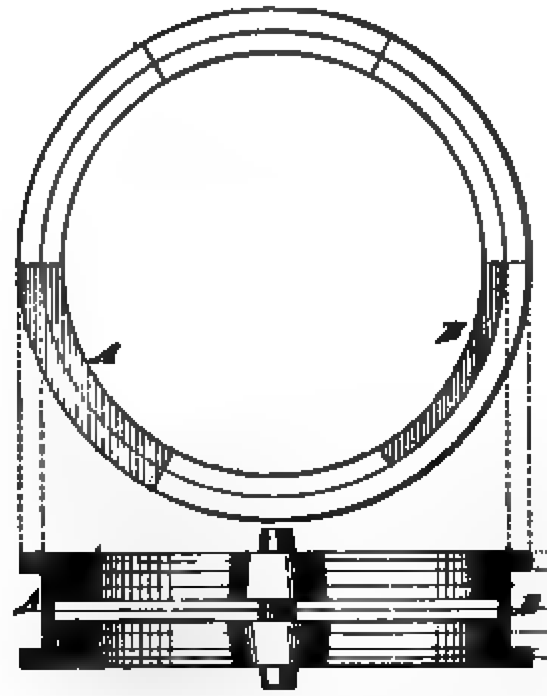
3162.

sions as will be most convenient for drawing from the model, and also for supporting each other after the model is removed. (See Fig. 3163.) Iron rods and stays are placed in the section while they are being hammered together, and channels leading from the top to the bottom must be formed in them through which to pour the metal. They are represented in the sectional cut, Fig. 3164. After this loam piece-mould is completed, a number of the sections are laid in a bed of loam in a flask, and the forming of the core is commenced within the cavity. It is made of the same material, a very fine loam, which was used for the outer mould, except that sometimes it has mixed with it a small portion of molasses or paste. It is hammered together in the same way, and when completed is a facsimile of the original model. It must contain an iron frame, or a number of iron rods, to strengthen it, and also some pierced tubing for carrying off the expanded gases which are generated in pouring. Iron rods must also be passed in two or more places through it, their ends entering and resting in the outer mould. When the latter has been carried up piece by piece and the hollow completely filled with the hammered loam, it is to be removed and the loam statue placed in the proper position, and its surface carefully pared down to a uniform depth. This forms the core, which is represented in Fig. 3162 by the smaller statue. When placed within the outer mould and properly adjusted, there will be a space, equal in depth to the thickness of the paring, between every part of the surface of the core and the inner surface of the outer mould. It will be observed that in this case the holes for pouring and for the escape of air are made at the base of the statue, which for casting is to be turned upside down. In casting statues in one piece, they are usually placed in this position. A

perpendicular section through both outer and inner parts of the mould and the containing flask has the appearance represented in Fig. 3164, with the exception that the iron framework for strengthening the parts has been omitted. *a a a* is the hollow mould; *b b*, channel in the cope for pouring the metal; *c c*, channel for discharging gases; *d d d d*, iron supports for holding core in place; *e e*, air-tube in core. Both core and outer piece-mould are now placed in the oven and baked, having previously been carefully dressed and cleaned, and then washed with a mixture of water and plumbago or charcoal, or both combined. After the proper amount of baking, which should leave them dry and porous, the parts are taken and placed together in a flask, each part of which contains a bed perfectly adjusted to the surface

3164.

3165.



of the mould. The flask is then carefully secured with bolts to prevent any expansion or opening of the mould during the casting.

PATTERN-MAKING.—The operations of the pattern-maker, conducted irrespective of the requirements of the moulder, involve considerations as to the strongest method of constructing the pattern; the amount of draught or taper to be given it to enable it to leave the sand easily; the amount by which the pattern is to be made larger than the required casting, in order to allow for the contraction of the metal while cooling in the mould; and the directions in which the grain of the different pieces of wood composing it should be, to prevent the pattern from warping and at the same time give it strength.

To give strength to a pattern, it is built up in pieces having the grain in different directions. An example of this kind is given in Fig. 3165, which represents a sectional side elevation and plan view of a pattern for a wheel. The thickness of the pattern is divided off into a sufficient number of courses to have each course of a convenient thickness. It is desirable, however, to have at least two courses in each flange, even though to accomplish this object those courses would be thinner than the others. The circles in the plan view are divided off into any convenient number of parts (in this case six parts), and lines drawn dividing these parts. From one of them, *A* in the cut, a templet is made for the pieces or segments to compose the flange; while from the second, *B*, a templet is made for a segment to form the body between the flanges. To these templets a sufficient number of pieces to form the respective parts of the pattern are made.

The building of the pattern is performed with the lathe-chuck on which the pattern is to be subsequently turned as a foundation. First, strips of paper forming a separating lining between the pattern and the chuck are glued to the latter, and upon this paper the first course of segments are glued, each segment being glued on its side face to the paper and on its ends to its neighboring segments. The second course of segments are glued to the first, with the joints in the middle of the first, so that all the joints shall not come in a line, which would weaken the pattern. In like manner a sufficient number of segments are laid to form half the pattern, the line of parting being at *A B*. When the glue is thoroughly dry, the pattern is turned up in the lathe, smoothed with sand-paper, and varnished, being much stronger and less liable to warp or distort than if made of a solid piece of wood.

The amount of taper or draught given to a pattern depends to a great extent upon its size. Very small patterns may be made almost parallel, while those entering deeply into the sand are given a taper of not less than one-sixteenth of an inch per foot, and in some cases three-sixteenths. The allowance usually made for the contraction of the casting is one-eighth of an inch per foot for brass

and one-tenth for cast iron. The shrinkage, however, is usually the most where there is the greatest body of metal, and patterns are sometimes made to bulge or protrude in those parts in order to provide for the surplus shrinkage.

Patterns are sometimes made so as to be to a certain extent variable, to suit the length of casting

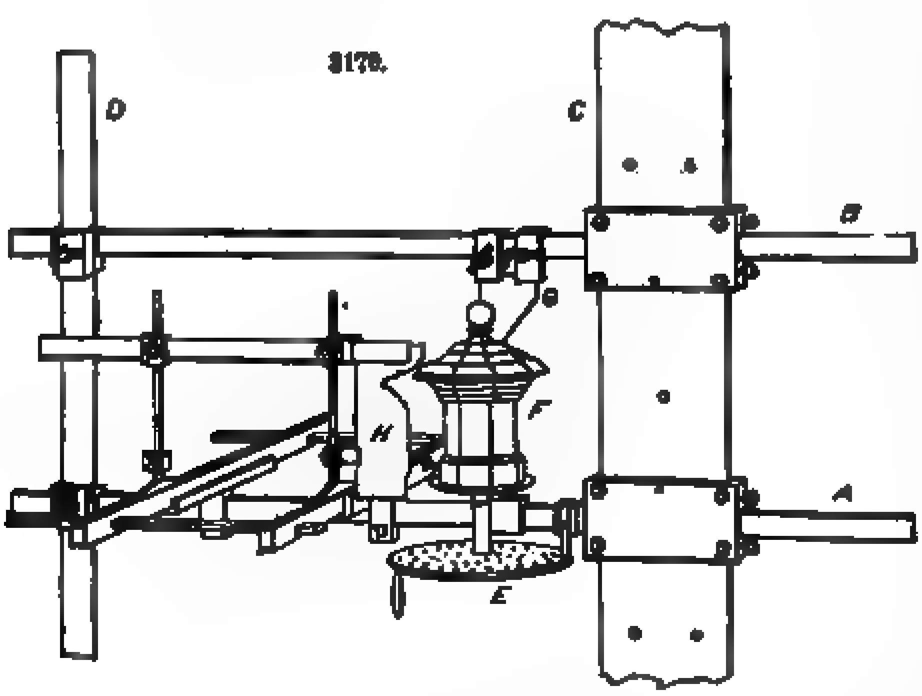
3166. 3167.

3168.

3169.

required. An excellent example of this kind is shown in Fig. 3166, which represents a pattern for an architectural column for a building. The body of the pattern is simply a box with a loose lid, as shown in Fig. 3167. The length of the pattern is determined by the stopping-off pieces A A. The base B and mouldings D, D', E, and E' are removable; hence the same base B may be used with longer or shorter panels E and E', or cables D and D', and it is only necessary to provide different lengths of patterns, for these latter parts permit the casting of columns of varying length. The ornamental panels are screwed to the block on one side only, the other being held in position by wire pins, which the moulder extracts after having rammed around them sufficient sand to hold them in position against the block. The block is extracted vertically from the mould, and the side panels are then extracted horizontally and lifted out. The apparatus for making the cores for these columns is also so designed as to permit the construction of cores of variable lengths. A cast-iron plate A, Fig. 3168, is provided, with the two vertical boards B B secured in the required width apart by the angle-straps D D. Core-bars G G are inserted, composed of tubes which afford vent to the gases and wings to hold the sand. The sand is rammed to the requisite length of core and leveled off on the top by the

3170.



strike-board *F*. To support the top of the boards, a clamp *F*, Fig. 3169 (which is an end view of the core apparatus), is employed.

SWEPT PATTERNS.—Fig. 3170 represents an apparatus for sweeping prismatic and circular patterns for light work, constructed by Mr. Jackson of New York. In this figure the horizontal bars are adjustable for distance apart and height upon the uprights *C* and *D*. *E* is an index-plate detained in any required position by the stop- and release-pin shown attached to the bar *A*, which also carries the bearing supporting the table *E*. On the spindle to which this table is attached, and above the bearing, is a smaller table carrying the mould *F*. *G* is a moulding-board attached to the bar *B*, and it is obvious that, by lifting the pin and releasing the table *E*, the latter may be revolved, and the board *G* will sweep the top of the pattern to its own edge conformation. To sweep the flat sides of the mould or core, the board *H* is moved reciprocally, the framework holding it being designed to permit of lateral movement. In Fig. 3171 is shown a moulding machine for either spur or bevel gear-wheels, the construction of which is as follows: The table is similar to that already described, and has a similar device (as shown) to release or detain it upon the upper table as before. The material of which the mould is formed is placed as shown at *M*. *A* is an upright carrying the horizontal arms *B C*, to which is attached the upright *U*, carrying the sweep *S*, which, being thus held stationary, operates when the table is revolved to sweep up either the inside or outside circular parts of the mould, including the flat face. The sweep at *E* for forming the teeth, or for sweeping up the mould for the arms, operates as follows: *P* is a piece sliding upon the bar *B*, and adjustable thereon by means of the lever set-screw at *L*. This piece is provided with vertical and horizontal joints at *V* and *H*, the two forming a universal joint, permitting the slide *D* to be set in any required position. Upon the slide *D* is the movable head *O* carrying the sweep *E*, and the line of motion of the latter is therefore regulated by the position of *O*, along which it slides, being operated by hand. In Fig. 3171 this machine is shown sweeping up the recesses in which the arms are to be moulded, or sweeping out the recess for the hub, as the case may be, while in Fig. 3172 the slide is shown with the sweep for the teeth in operation, the bar *O* standing vertical. J. R. (in part.)

MOULDING MACHINES, WOOD-WORKING. These machines are used for the manufacture of ornamental mouldings for buildings, and cabinet and railway-car work. They are commonly distinguished as *outside moulding machines*, which have a bed with two or three of the heads outside the frame of the machine; and *inside moulding machines*, which have all of the heads and the table inside the frame. Outside moulding machines are perhaps most commonly used, and can be adapted for various purposes besides moulding, as working flooring and ceiling. They are constructed with one, two, three, or four heads, according to the character of the work to be done. Inside moulding machines are constructed with three or four cutter-heads, and are adapted to surfacing or any work up to 12 in. in width. They are designed for the production of light and heavy mouldings and general work of every description, and, when furnished with matching-heads, can also be used for tonguing and grooving, flooring and ceiling, up to 12 in. in width. A prominent manufacturer of these machines states that he constructs them with heavy-weighted feed-rolls, expansively geared, with slotted steel cylinders for upper and lower arbors, slotted side-heads of gun-metal or steel, vertical adjustment of the upper cylinder, improved clip for preventing tearing in working cross-grained lumber, and flexible pressure-bars. The cylinders and side-heads of these machines are usually made to take on four knives, having slots planed on all four sides, and they may be accurately adjusted. Among the special forms of moulding machines are the following:

The universal wood-worker is a combination of the outside moulding machine with a machine for planing out of wind, grooving, gaining, etc. This is designed for straight work.

The edge-moulding machine has the heads placed vertically in the table, and is designed for moulding the edges of carved work.

The carving or recess-moulding machine is designed for working forms of panels on the face of the work, and usually can be employed for edge-moulding.

Outside Moulding Machines.—Fig. 3173 represents an outside moulding machine designed for light mouldings, sash, door, and blind work, or narrow flooring. It is made to work 6 or 8 in. wide, and on either three or four sides, as may be wanted. The cutter-head is of steel, slotted on all four sides. The side-heads are of steel and slotted, and revolve on steel arbors, which have a lateral adjustment sufficient to take in stuff up to 6 in. wide. Both side spindles have vertical adjustment, and the outside spindle can be swung to an angle. The under head is provided with an adjustable throat, and can be quickly adjusted to the thickness of the cut. The bonnet and attached pressure-bar can be

3173

instantly thrown back clear of the upper head. It has two feeding-rolls of large diameter, with two changes of speed, and strongly geared, and their motion is instantly started or stopped by means of a lever. The table or platen has a vertical movement. The tight and loose pulleys are 8 in. in diameter, 4 in. face, and should make 875 revolutions per minute.

Inside Moulding Machine.—Fig. 3174 represents an improved form of two-roll inside moulding and beading machine, which will work mouldings on one or both sides 12 in. wide or under, and up to 5 in. in thickness. It also planes, tongues, grooves, and beads material 12 in. wide. The cylinders are made from solid cast steel, belted on each side, and run in large patent self-oiling bearings,

slotted on each face, enabling the cutters to be set at varying angles, and capable of sticking any size of moulding by using cutters on all four sides, thus equalizing the cut and utilizing the power. The under cylinder has a vertical adjustment, graduated to different thickness of cut while in motion; and by loosening one bolt the pressure-bar and stands can be swung entirely clear of the cylinder, giving free access to the cutters for purposes of sharpening or adjusting. A beading attachment is placed upon the pressure-bar, over the under cylinder, so as to gauge the depth of the bead from the surface of the board, thus securing an automatic adjustment of the beading-shaft at all times. The upright spindles can be moved vertically or horizontally while in motion, the outer spindle to any angle desired, and self-oiling bearings and steps are provided. The side-heads are made of steel, and the arbors have a lateral adjustment on separate platens, and are provided with lock attachment for preventing the possibility of movement after the heads are brought to the desired position; a chip-breaker is provided for holding the fibre of the wood while the side cuts are being made. The machine has two feeding-rolls of large diameter, the upper one made in sections fitted with a weighting attachment and pivoted boxes, which secures an equal pressure on the lumber being worked, regardless of any inequalities in the thickness. The rolls are connected by expansion-gearing, which allows the upper roll to adapt itself to the varying angles on irregularly sawed lumber. The stuff being worked may be quickly withdrawn from the machine by elevating the feed-rolls by means of a lever. The tight and loose pulleys are 12 in. in diameter and 6 in. face, and should make 600 revolutions per minute.

Variety Wood-Workers.—These machines are among the most ingenious of the many forms of apparatus used for wood-working. They are chiefly remarkable for the multiplicity of purposes to which they may be adapted. These include planing straight or out of wind, tapering, rabbeting door and window frames, rabbeting and facing inside blinds, jointing, beveling, chamfering, ploughing, making glue joints, raising panels, ripping, cross-cutting, tenoning, circular moulding, dovetailing, etc. They are constructed in two varieties, to work either one, two, three, or four sides, with separate arbors and outside bearing supports on each side; also with a main arbor extending from one side to the other, with patent outside bearing supports. This latter form of machine is of cheaper construction. Both sides of the machine are driven from one countershaft, arranged so as to convey the power to both sides simultaneously or separately, as the operator may desire. This method of obtaining independence of the combination allows the operator to perform the work on either side without interfering with the other. This is accomplished by means of a double friction-pulley upon the countershaft, carrying two belts and operated by two levers.

3174.

Fig. 3175 represents the moulding side of one of the most improved forms of universal wood-workers, built by Messrs. J. A. Fay & Co. of Cincinnati. Fig. 3176 shows the wood-worker side. There are two 8-in. and two 4-in. slotted steel heads and cutters on the moulding side, and one three-knife head and cutters with outside removable bearings on the wood-worker side. This forms the complete machine for doing all the different varieties of work shown and described further on. It will surface both sides, and tongue and groove or joint flooring, ceiling, etc., up to 8 in. wide. The additional head (the under cylinder) has an independent adjustment to suit the thickness of the cut, and with the side-heads raises and lowers vertically with the platen or bed.

Fig. 3177 represents a universal jointer and wood-worker made by Messrs. Beutel, Margedant & Co. of Hamilton, Ohio. This has a triangular cutter-head and novel means for adjusting the tables at any desired angle.

Fig. 3178 is the Excelsior universal wood-worker of the same makers, arranged as a moulding ma-

chine. The table or platen consists of a large main support, on which a side-bracket is raised and lowered independently of the other adjustment of parts; also of two tables independently adjustable

3175.

in a horizontal plane; all of which can be raised and lowered at either end of the machine, by means of a crank-wrench, which engages two screws connected by corresponding gearing. The main support can be elevated or dropped for certain purposes independently of the horizontal position and

3176.

perpendicular adjustment of the side-bracket in front of the cutter-head. In the engraving both tops are shown at a common level. The large one rests partly on the main support, and on the side-bracket the smaller table is carried forward to the projecting side-head sufficiently to permit the free

3177.

working of the same. The table may be brought forward, and the opening entirely inclosed if the side-head is not needed; the machine will then operate as a single-head moulder and sticker. The

side-head can be raised and lowered, moved in or out, set at any angle, and adjusted either way, keeping the angular position given. The upright countershaft of the side-head, driven by strong friction-gearing, enables the operator to start or stop the side-head at will, while the material is moved forward by the feed-rollers, and operated upon by the central cutter-head.

Figs. 3179 to 3212, with the accompanying descriptions, show the best methods of manipulation to produce some of the various forms of work which may be done on the universal and variety wood-workers. The machine should be placed so that the table will be on a perfectly level plane. If, when the level is placed lengthwise and crosswise of the table, they are found to be exactly true, then the parts of the machine are correctly in line, as the strength of the frame renders it impossible for it to warp out of true.

Fig. 3179 shows the position of the hands and table in the operation of truing up or planing out of wind. The back table should be on a level with the periphery of the cutting edge. The thickness of cut is regulated by lowering the front table.

Fig. 3180 shows the operation of plain cornering or bevel-edging. The fence is set to the angle required, and the front table is lowered to the depth the corner is desired to be cut. Fig. 3181 shows the beveled work.

Fig. 3182 shows the process of cornering or chamfering part of the way on a piece, or between the ends. In this method both tables are lowered to an equal distance below the cutting edge, according to the depth to be cut. Fig. 3183 exhibits the work.

Fig. 3184 shows the tables in the same position as the preceding examples, with the addition of a box constructed to correspond to the shape of the piece to be cornered, and the stops placed permanently in the box. By this arrangement duplicates can be produced at any time with exactness.

Fig. 3185 shows the position of the tables in cutting a taper, as represented in Fig. 3186. The back table should be raised to the position indicated in Fig. 3179, and the front table lowered sufficiently to bring the line of the desired taper on a line with the back table. This process can be applied also to straightening a tapered piece, or one that is crooked or curved.

In mitering or forming joints at any angle, the fence is set to correspond to the desired angle, and the front table lowered to cut off the form at one operation. Fig. 3187 shows the process of mitering, which can be done as well across the grain as with the grain, and a miter thus made forms a perfect joint, Fig. 3188. In this operation a straight cutter-head is used.

Fig. 3189 shows the method of arranging the tables for rabbeting. The tables are set to one level, the rabbeting-head being substituted for the planing-head. The rabbeting-iron is inserted between the tables, forming a connection between them, and thus giving a support for the stock being worked.

Fig. 3190 represents the position of the material while being rabbeted. The width of the rabbet can be made as great as the length of the rabbeting-head, and gauged to the desired width by the fence. The depth of the rabbet, Fig. 3191, is graduated by the vertical movement of the tables.

Fig. 3192 shows the machine arranged for tenoning. In the operation of halving or tenoning, the rabbeting-iron is used as in rabbeting, Fig. 3193. The tables are placed on the same level, and a slide arranged to fit in the grooves in front. The lengths of tenons can be gauged by the fence, or by stops on the slide, and the slide can be fixed to cut square or angle tenons. The same cutter-head is used as in rabbeting, and the tenon may be made longer than the cutter-head by repassing the stuff over as often as may be necessary to increase the length.

Fig. 3194 shows the back-board for panel-raising, which is fastened to the fence, the tables being adjusted to the same level. The depth of panel is regulated by the distance the tables are lowered below the highest point of the cutting edge of the heads. A panel-iron is inserted between the tables and between the heads for the support of the panel being cut.

Fig. 3195 shows the panel (Fig. 3196) being passed through the entire attachment in use. The front board is attached to a fence by bolts passing through springs placed between the front fence and front board, thus giving a flexible pressure for inequalities in thickness. The front fence is attached to a slide-board in the front groove of the table by angle-irons, slotted for graduating to the thickness of the panels.

Fig. 3197 shows the process of hand-matching or tonguing and grooving (Fig. 3198). The

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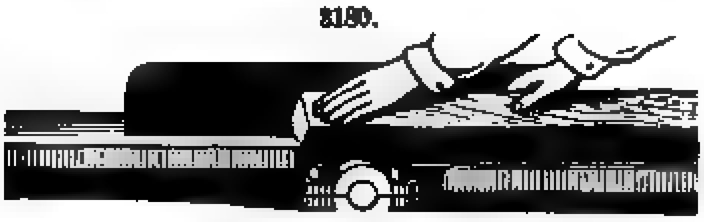
3180.



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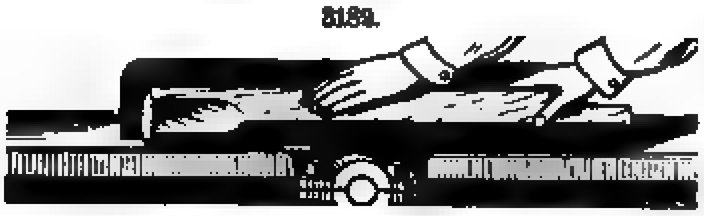

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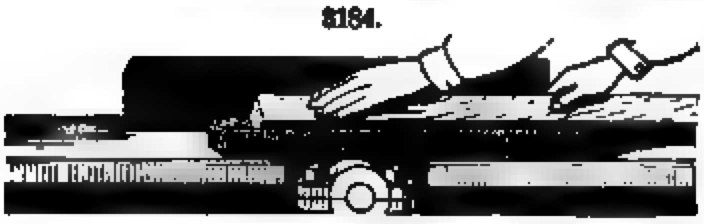

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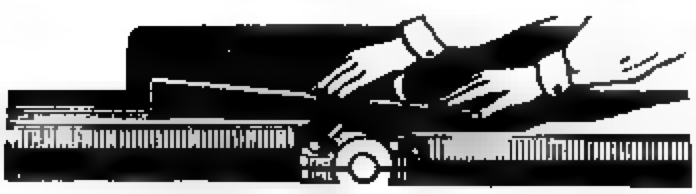

3189.

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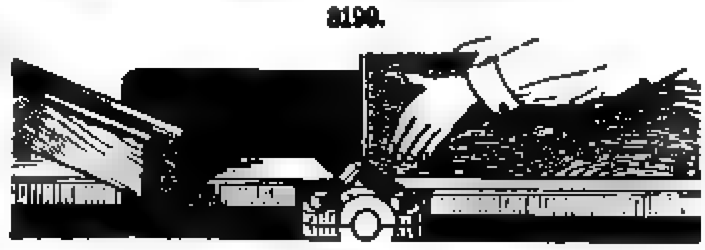

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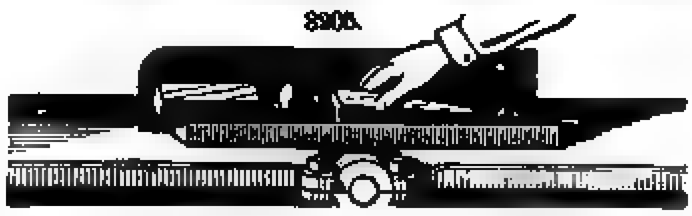

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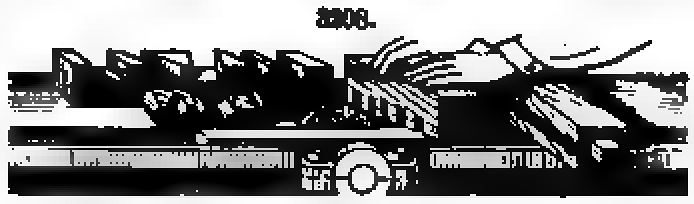

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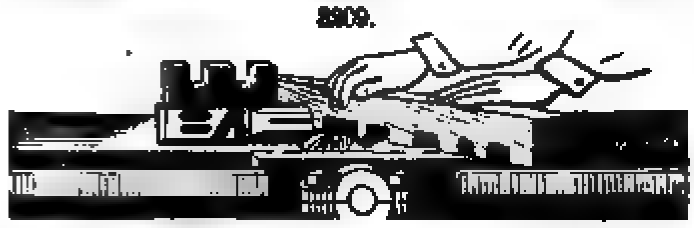


3211.

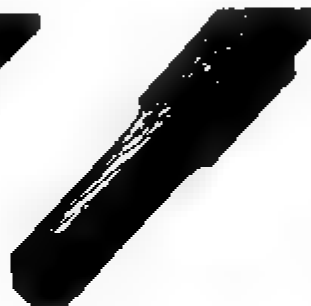
matcher-heads are placed on the mandrel, the fence forming a guide for the back head, and a fence attached to a side board adjusted to the front head, forming a guide for it. By placing the fences at an angle, tongues and grooves can be cut to any angle.

The operation shown in Fig. 3199 is that of making rule or table joints (Fig. 3200), performed by the same process as in hand-matching, heads and cutters to suit the required joint being substituted for the matcher-heads.

Fig. 3201 shows the operation of grooving or ploughing. This is performed with the grooving- or

3181.

3185.



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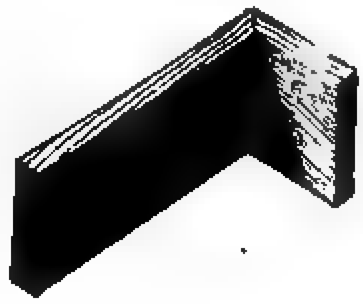

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3193.

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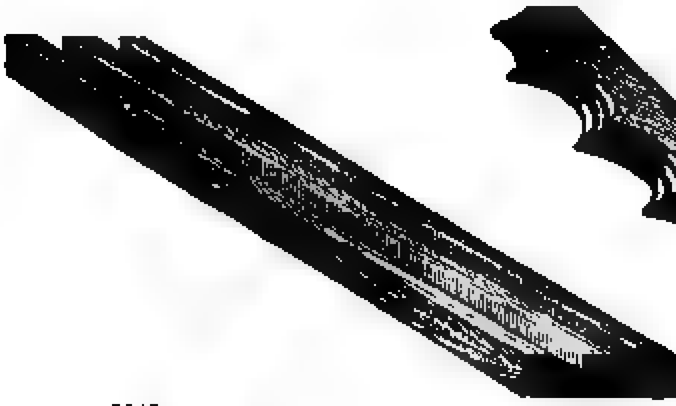
3200.

3202.



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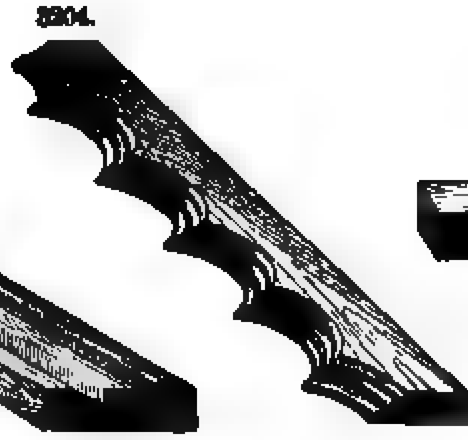
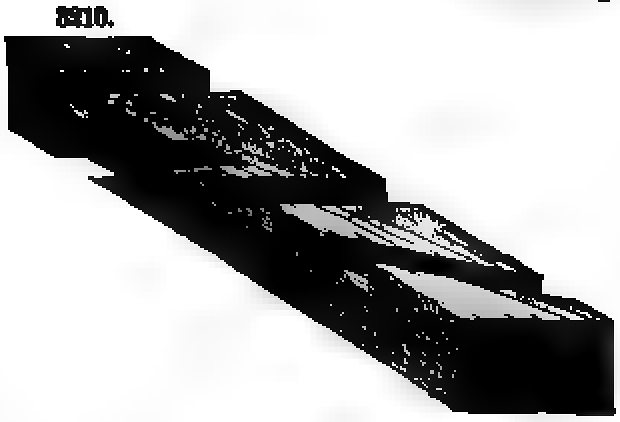


3206.

3210.



3212.

gaining-head, and one or more grooves (Fig. 3202) can be cut, as in window-frames. In grooving, the tables are on the same level, and the depth of the groove is gauged by the distance the tables are lowered below the periphery of the cutters.

Fig. 3203 shows the tables arranged for working waved moulding (Fig. 3204), similar to that done on a shaper and friezer. A collar is placed on the cutter-head or spindle, against which the* pattern upon which the moulding is to be worked is fastened. This is passed over the head with the fence for

a guide, the tables being lowered sufficiently to allow the pattern free motion over the spindle. Oval and circular waved moulding can be made by constructing proper guides as indicated above.

Squaring up the unturned parts of newels, balusters, etc. (Fig. 3206), is done with the straight cutter-head. Fig. 3205 shows the method of dressing between the turned parts, which is the same as shown in Fig. 3184, with the plain corner box, or by making a sliding box into which the piece is placed and passed over the cutter-head with the form in which it rests.

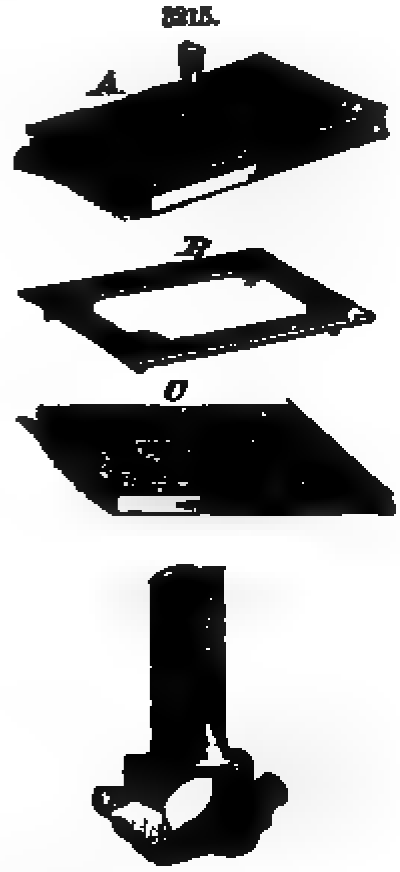
As shown in Fig. 3207, a circular ripping or cross-cutting saw can be placed on the mandrel between two collars, and the opening between the tables filled with a board fitted to the tables, making a continuous saw-table, upon which ripping to any bevel or cross-cutting to any angle can be done.

3213.

For the purpose of gaining (Fig. 3210), the tables, Figs. 3208 and 3209, are placed on the same level, with the slide in the back of table across the opening between the tables. The depth of the gain is gauged by the distance of the table below the cutting edge of the gaining-head. The slide-board of the gaining-frame is placed in the groove in front of the table, with the guide-bar at right angles to the gaining-head. The stock is placed in front of the guide and operated as in cross-cutting.

3214.

3215.



Oval and circular mouldings, as shown in Fig. 3212, can be worked on these machines. The form fastened to the tables is of the same thickness and shape as the inside of the segments. A holding-board should be made the same circle as the outside of the segments and half an inch wider than the segment, to extend over and bear against the form. The mode of operation is shown in Fig. 3211.

Edge-Moulding and Friezing Machine.—Fig. 3213 is an example of the form of machine used for moulding the edges of carved work. The cutters are affixed to and revolve with the spindle shown at *A*, and the table is raised and lowered by the hand-wheel. Devices are provided to prevent the table from turning and for the adjustment of the bearings of the spindle. The arrangement of the cone-bearings for the spindle is shown in section.

Carving, Paneling, Edge- and Surface-Moulding Machine, Fig. 3214.—This class of machine is

3216.

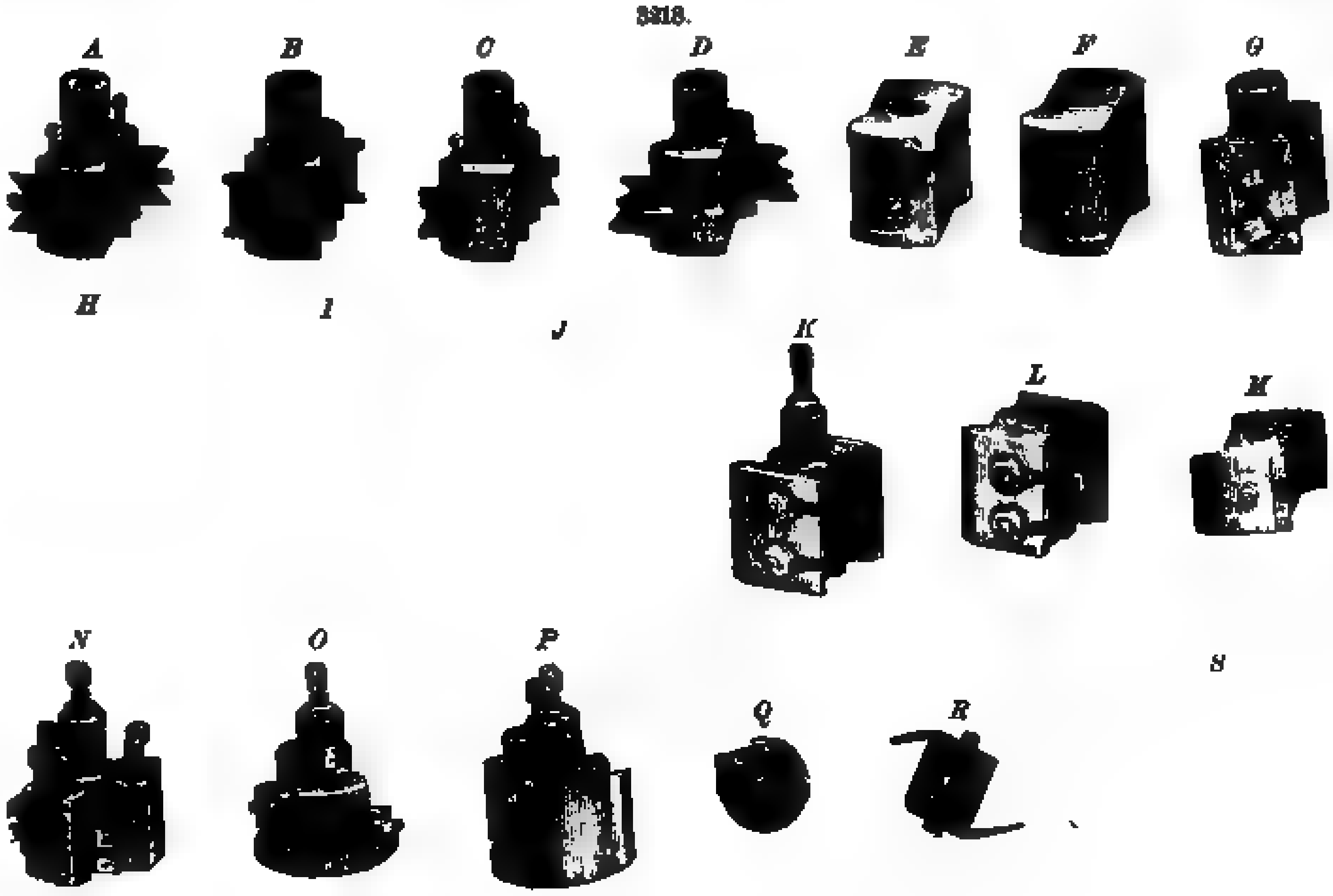
A *B* *C*

3217.

D *E*

employed for producing carvings and recessed or relieved panel-work, and for ornamental bracket-work. The form of tool *A* used is carefully shaped to suit the requirements of the work, and is revolved at high speed in the vertical spindle, the work being fed and operated against and beneath the tool. The table is adjustable for height and to suit the thickness of the work by means of the

3218.



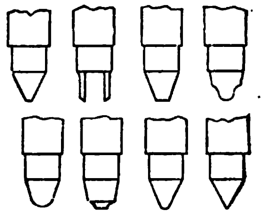
hand-wheel shown beneath the table. It is elevated to bring the work into contact with the tool to the required depth by means of a notched treadle, and the finished work is readily removed by the operation of an auxiliary treadle, which disengages a pawl and allows the prime treadle and the table to drop to its original adjusted position.

Fig. 3215 shows the method of paneling or cutting designs in solid wood in this machine. A perspective view of a cutter is shown underneath, and other forms of cutters are represented in Figs.

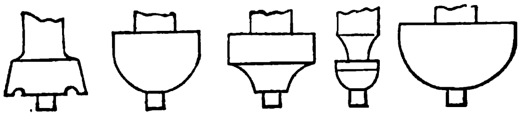
3219 to 3222. A templet *B*, of the desired form, is placed over the piece *A*, upon which the panel is to be made. A space is left between templet and work for the escape of chips. The panel when finished appears as at *C*.

CUTTER AND CUTTER-HEADS.—Moulding cutters are produced by milling into the face of the steel so as to produce the desired shape of the moulding. This method is claimed to be better than cutting the required shape on the ends and then grinding to a bevel. In Fig. 3216, *A* and *B* are sash-cutters, *C* and *D* door-cutters, and *E* is a double bead-cutter. Fig. 3217 represents a group of moulding cutters. In Fig. 3218 are represented the different forms of heads used. *A* and *B* are sash-heads; *C* is a door-head: *D*, *E*, *F*, and *J* are moulding heads; *G* and *I* are planing heads; *H* and *L* are slotted heads; *K* is a combination top-screw head; *M* is a side head; *N* is a three-wing matcher; *O* is a two-wing matcher; *P* is a jointing head; *Q* is a beading head; *R* is a cope-head; and *S* is a patent grooving head. Matching heads are made usually with two or three wings as shown. Slotted heads receive any kind of cutter without regard to the position of the slots. Gaining and grooving heads are usually made of gun-metal or steel, accurately finished and balanced, and provided with steel set-screws.

3219.



3220.



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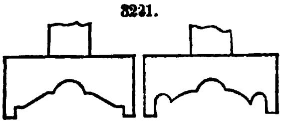

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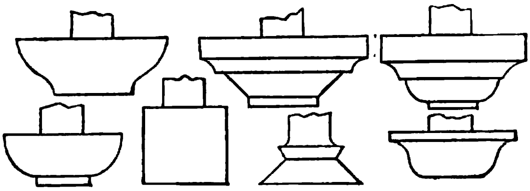


In Figs. 3219 to 3222 are represented various forms of cutters used in carving and paneling machines. Those shown in Fig. 3219 are carving, penciling, tracing, and surface-ornament tools. Those in Fig. 3220 are edge and bracket-moulding cutters; in Fig. 3221, rosette-cutters; and in Fig. 3222, surface or paneling cutters. J. R. (in part).

MOULD-RAMMING MACHINE. See MOULDING.

MOUNTAIN RAILROAD. See RAILROADS, MOUNTAIN.

MOWER. See AGRICULTURAL MACHINERY.

MULE. See COTTON-SPINNING MACHINERY, and WOOL MACHINERY.

MULEY SAW. See SAWS.

NAILS AND NAIL MACHINERY. Nails are either wrought or cut from metal, or cast. Cast nails are generally of inferior quality and of little use. Nails are assorted as to purpose, as hurdle, pail, deck, scupper, sheathing, fencing, etc.; as to form of head, as rose, clasp, diamond, clout, etc.; as to form of point, as flat, sharp, spear, clinch, etc.; as to thickness, as fine, bastard, strong; as to size, from 1¼ lb. to 40 lbs. (that is, 1,000 nails of a given size will weigh so many pounds); as to material, as copper nail, galvanized, etc.; and, as already noted, according to method of manufacture. The following table of weights and nomenclature is commonly employed:

Table of Names and Weight of Nails (Trautwine).

NAME.	Length, inches.	Number per Pound.	NAME.	Length, inches.	Number per Pound.
3-penny.........	1	557	8-penny.	2½	101
4 "	1¼	353	10 "	2¾	68
5 "	1¾	232	12 "	3	54
6 "	2	175	20 "	3½	34
7 "	2¼	141			

Wrought Nails.—One of the most improved methods of manufacturing wrought nails is from iron produced by means of grooved rolls, having either one or two ridges raised on its surface, the former if for "brads," the latter if for rose-headed, or clasp, etc. The ridges cross the strut in order to preserve the fibre of the iron parallel with the length of the nail, and the sheet is cut up into breadths which have on one side a single or double ridge, according to the variety of nail required. These strips are next heated, presented to the machine, drawn in by it, and cut by a "slicer" crosswise into breadths, each of which ultimately forms a nail, which are picked up by a "carrier" forming part of the machine, and placed in a "grip" made by three dies. The "slicer" alluded to forms the fourth side, and is firmly held during the process of tapering (accomplished by the pressure of a roller-die). While in this position, a die, with a depression corresponding to the form of the head of the nail, is impelled against the surplus projecting metal, and converts it into a finished

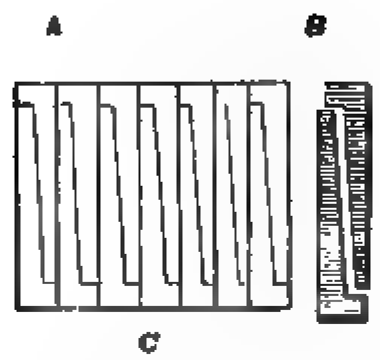
head, the complete nail dropping out of the machine. It may be added that the present method of producing machine-made wrought nails is a hybrid process, between cut- and wrought-nail making, the shank being cut, and the heading and pointing being done by a die and a roller.

Cut Nails.—In cut nails the metal is operated upon cold. Pointing forms a special operation in both hand- and machine-wrought nails; but in cut nails, the production of shank and point is simultaneous. It is only when the cut nail requires to be headed that an additional process is added, though performed by the same machine by which the cutting is accomplished. All cut nails are produced from strips of iron cut from sheets, the breadth of the strips corresponding to the length of the nail. Care is taken that the fibre of the iron runs parallel to the length of the nail, by laying a number of joiner's "sprigs" (*B*, Fig. 3223) or shoemaker's "sparrables" (*A*) head to point alternately; and thus a strip is reproduced, corresponding in breadth to that from which they were cut. Brads (*C*) are also cut out of each other from a strip broader by the head; in the production of these, or any other cut nails, there is no scrap or waste. "Headed" cut nails, as rose, clasp, slate, clout, and those of the "tack" group, are simply larger "sprigs," wedge-like in breadth, equal in thickness to the sheet iron from which they are made. After they are cut off from the strip by the slicer of the nail-cutting machine, they drop into and are firmly clutched by grips, and a heading die carried by a sliding bar "upsets" the iron projecting from the grips and converts it into a head.

Fig. 3224 will serve to represent the general mode of operation of nail-cutting and -heading machines. The nail-strip *A* is placed in a feed-box, vertically or horizontally, and receives a vibratory motion to give the taper to it; the strip is pressed upon by a spring to keep it in contact with the slicers. The top slicers are fixed in the framework of the machine, as are also the back dies *E' E*, while the bed-shear *C*, with its bottom dies *B' B*, is moved to and fro in a slide. The figure shows the slide at its farthest point of stroke on the right-hand side. A nail-blank is pressed against the

3224.

3223.



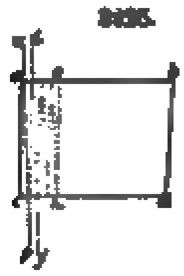
back die *E'*, and the bottom die *E* is lifted up vertically. Thus the blank is firmly held upon four sides, while the heading-bar is brought into action upon the end of the blank to be headed. After it is cut off, it is advanced by a finger *F'* just as much as is required to form the head. The instant the nail is headed, the dies *C* and *B* travel in the direction of the arm, by which time the nail-strip *A* is in its place for the slicer to cut off another blank; and on the return stroke of the slide, the headed nail is free and is pushed downward by the finger *F'* placed at the back of the top slicer *D*. The slide carries the blank *N* against the die *E*, and the operation as described is repeated. The machine represented is a double-action one, having two headers which operate alternately, i. e., on the retreat and return stroke.

Lawrence's self-feeding machine, invented by Mr. John Lawrence of Philadelphia, is one of the most ingenious yet devised. We take the following description from *Engineering*.

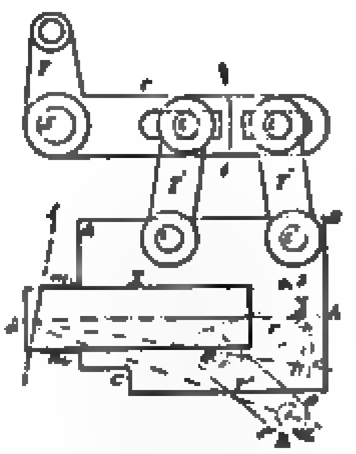
In cutting up a strip of iron into nail-blanks, a problem which is theoretically very simple has to be solved. Let *a b c d*, Fig. 3225, represent the strip of iron to be cut into nail-blanks, and let the dotted lines between *a g c h* denote the lines of the necessary cuts. The line *e f* indicates the plane of the cut made by the knife at each reciprocation of the machine. As it is necessary that the strip shall be cut up into taper blanks, it is manifestly impossible to feed the machine by simply sliding the strip forward toward the knife; because, if this were done, the second cut would be on the line *i j*, and each blank after the first would be a parallel piece of iron, allowing neither for the heads nor points of the nails. In Fig. 3226, *a b c d* represents the position of the strip for the first cut, and the line *e f* shows the plane of that cut. The dotted rectangle *a' b' c' d'* indicates the position assumed by the strip for the second cut. It is evident that, by simply inclining the strip from side to side, as shown, and at the same time feeding it forward to the knife, the required taper blanks can be produced. Fig. 3227 is a diagram showing how the strip is moved in the machine. The strip is shown at *X*, in the position which it occupies on the feed-table *A B C D*. The dotted line *a b*

shows the angular position of the strip for the first cut, and the dotted line *a d* indicates that for the second cut. The cut coincides with the line *j k*. The motions of the feed-table and strip are produced and controlled in the following way: The main gearing of the machine rocks the bell-crank

3226.



3227.



3228.

lever *V* upon its fulcrum *S*, and the longer arm of this lever moves the table by the links *T'*, so causing the centre-line of the strip *X* to alternately coincide with the dotted lines *a b* and *a d*. Therefore the feed-table moves round an imaginary centre at *a*; and the nail-blanks are thus cut taper, while the wider end of each alternate blank is cut from alternate edges of the strip *X*. The strip is fed forward toward the knife between each cut by means of feed-rollers having a step-by-step movement. It will be perceived that the ends *t* of the links *T'* are adjustable along the lever-arm *V*, so as to allow for altering the amount of taper in the blanks to suit different sorts of nails. Inasmuch as the imaginary centre *a* is beyond the line *j k*, the strip has a slight movement of lateral translation where the cut is made. It is absolutely necessary to the proper working of a cut-nail machine that, at the moment when the knife rises after making the cut, the strip should be drawn back clear of the rising knife. This is done by means of the link *r*. In the main framing of the machine under the feed-table is the stud *p*, upon which the link *r* works. The other end of the link *r* engages with the stud *q* on the under side of the feed-table. As the rocking action of the lever *V* turns the feed-table about the imaginary centre *a*, the point *q* in the line *a b* would necessarily move to *i*, because the arc *g h* (struck from the centre *a*) cuts the centre-line *a c* at *i*. But the action of the link *r* causes the point *q* to describe the arc *e f*, and thus the table is drawn back by the link *r* to the extent of the difference of the curvature of the two arcs *g h* and *e f*, so keeping the strip clear of the rising knife. Equally the same action of the link slides the strip forward again by the time that its centre coincides with the line *a d*.

Fig. 3228 shows the method adopted for enabling a large number of strips of iron to be placed one upon another in the feed-box of the machine. The strips are placed in the feed-box *J*, which can be filled to the top if necessary. The spring "feeler" *N* works with a rapid vibratory action, and whenever the feed-rollers *L* draw the strip which is being cut as far as their proper action can take it, this "feeler" *N* thrusts another strip between them. The strip so thrust between the rollers is at once fed forward toward the knife, and the short piece of the previous strip left between the rollers and the knife is of course pushed forward and cut up to the very end. The springs *m* and the guide *B* serve to steady these short ends while being cut up.

Finish of Nails.—The after-finish of tacks or nails which are blue-black or tinned is as follows: The blue color is the result of placing the cut tacks in an iron cylinder and subjecting them to the heat of a muffle, and when the required shade is obtained they are withdrawn and allowed to cool. The black is produced by immersing the tacks in black varnish and then drying them in a stove. The white or tinned tacks are coated with tin by immersion in a bath of that metal in a state of fusion, the tacks having been previously cleansed by the action of sulphuric acid diluted with water.

Iron-Wire Nails.—Nails are also made from iron wire, a variety of French origin, as the name, *pointes de Paris*, indicates. They are made from 1 to 4 in. in length, and are well suited for, and principally used in, the construction of packing cases of willow or other soft woods which grow so abundantly on the Continent. These nails drive freely and hold firmly, the material rendering them strong, while the parallelism of the shank presents an obstruction in withdrawing them when once driven. They are all made by machines, which cut the wire, point, and head, by means of advancing dies, the point formed by one die, the head by another, as in machines used in the formation of the heads of machine-made, wrought, and cut nails.

Cast Nails.—Nails are also cast, but their use is chiefly confined to horticultural purposes, such as the training of fruit-trees against walls; hence their name "wall" nails. Cast nails are also used for the attachment of laths to the interior walls of buildings to hold the plaster. These have tapering shanks, square or triangular in section, and are cast in moulds formed of sand, from patterns which represent the heads only, the shanks being pricked in with a model representing the spike in the corresponding half of the mould, directly opposite the centre of the head pattern; or a complete pattern of the nail is projected through a thin metal plate, the head on one side, the spike protruding on the other. These are moulded in a two-part casting-flask or mould, the head on one half, the stalk on the other. Sometimes the nail is laid in a longitudinal direction, one half on one side, the other half on the reverse of a thin metal plate, and then moulded. After the mould is made, the impressions produced by the patterns are connected to central "gets" or runners. The moulds, being closed, are bound together with ordinary moulder's clamps, so that the iron in a state of fusion

is run in and fills the prints made by the patterns. When cooled, the moulds are opened, and the nails disconnected or broken off from the "gets." Like all iron castings, these nails are brittle and frequently break in driving, which could only be obviated by annealing them in close iron boxes filled with hematite iron ore. This process, however, would be expensive, and even when annealed the nails would not be so well fitted for general use as hand-wrought, machine-made, or cut nails.

Cast brass nails, with square or twisted shanks, are produced in small quantities for ship-building purposes, and of an alloy of copper and tin, chiefly used for the fastening of copper or patent sheathing to the hulls of ships below the water-line.

Adhesion of Nails.—It has been determined by experiment by Mr. B. Bevan, that the resistance to entrance of nails in wood is greater than the resistance to extraction, by a ratio of about 6 to 5. The percussive force required to drive the common sixpenny nail to the depth of 1½ in. into dry Christiania deal, with a cast-iron weight of 6.275 lbs., was four blows or strokes falling freely the space of 12 in., and the steady pressure to produce the same effect was 400 lbs. A sixpenny nail driven into dry elm, to the depth of 1 in. across the grain, required a pressure of 327 lbs. to extract it; and the same nail driven endwise or longitudinally into the same wood was extracted with a pull of 257 lbs. The same nail driven 2 in. endwise into dry Christiania deal was drawn by a pull of 257 lbs.; and to draw out one inch under like circumstances took 87 lbs. only. The relative adhesion therefore in the same wood, when driven transversely and longitudinally, is as 100 to 78, or about 4 to 3, in dry elm, and 100 to 46, or about 2 to 1, in deal; and in like circumstances the relative adhesion to elm and deal is as 2 or 3 to 1.

The progressive depths to which a sixpenny nail was driven into dry Christiania deal by simple pressure were as follows:

Depth, inches, .25, .5, 1, 1.5, 2.

Pressure, lbs., 24, 76, 235, 400, 610.

In the above experiments, great care was taken by Mr. Bevan to apply the weight steadily, and toward the conclusion of each experiment the additions did not exceed 10 lbs. at one time, with a moderate interval between, generally about 1 minute, sometimes 10 or 20 minutes. In other species of wood the requisite force to extract the nail was different. Thus, to extract a common sixpenny nail from a depth of 1 in. out of dry oak required 507 lbs.; out of dry beech, 667 lbs.; and out of green sycamore, 313 lbs. From these experiments we may infer that a common sixpenny nail, driven 2 in. into oak, would require a steady pull of more than half a ton to extract it. Ridged or Chelot nails have been made and experimented upon in France with good results.

NARROW GAUGE. See RAILROADS, CONSTRUCTION OF.

NICKEL-PLATING. See ELECTRO-METALLURGY.

NITRO-GLYCERINE. See EXPLOSIVES.

NOTCHING. See CARPENTRY.

NUT-FORGING. See FORGING MACHINES.

NUTS AND BOLTS. Bolts are chiefly used to resist straining forces acting parallel to the axis of the bolt, and normal to the surfaces held together. When in shear, they are subject to the same rules as rivets.

Strength of Bolts.—(For screw-threads of bolts, see SCREW-THREAD.) The strength of screw-bolts is approximately estimated as follows: For press-screws and other bolts which do not require to be tightened before the load comes upon them, the working stress per unit of area (which hereafter will for brevity be denoted by f) may be taken at 6,000 lbs. per square inch. For accurately-fitted bolts requiring to be tightened moderately, $f = 4{,}000$. But for bolts which are used to draw joints steam-tight, and which must be greatly tightened before the steam-pressure begins to act, f ought not to exceed 1,600 or 2,000 lbs. per square inch. Putting $P =$ the axial straining force acting on the bolt and $d =$ diameter of bolt, the following equations have been deduced:

$$d = .055 + 1.127 \sqrt{\frac{P}{f}} \text{ for triangular threads.}$$

$$d = .085 + 1.32 \sqrt{\frac{P}{f}} \text{ for square threads.}$$

When twisting moment is considered, this adds about 15 per cent. to the diameter necessary for the bolt. The following table shows the strength of bolts screwed up tightly, Q representing the assumed value of the force used in screwing up. The real stress is taken at $f = 9{,}000$ lbs. The pull on the spanner is taken at about 10 lbs. for each 1,000 lbs. on the bolt, and the twisting moment is taken into account.

Table showing Strength of Bolts screwed up tightly.

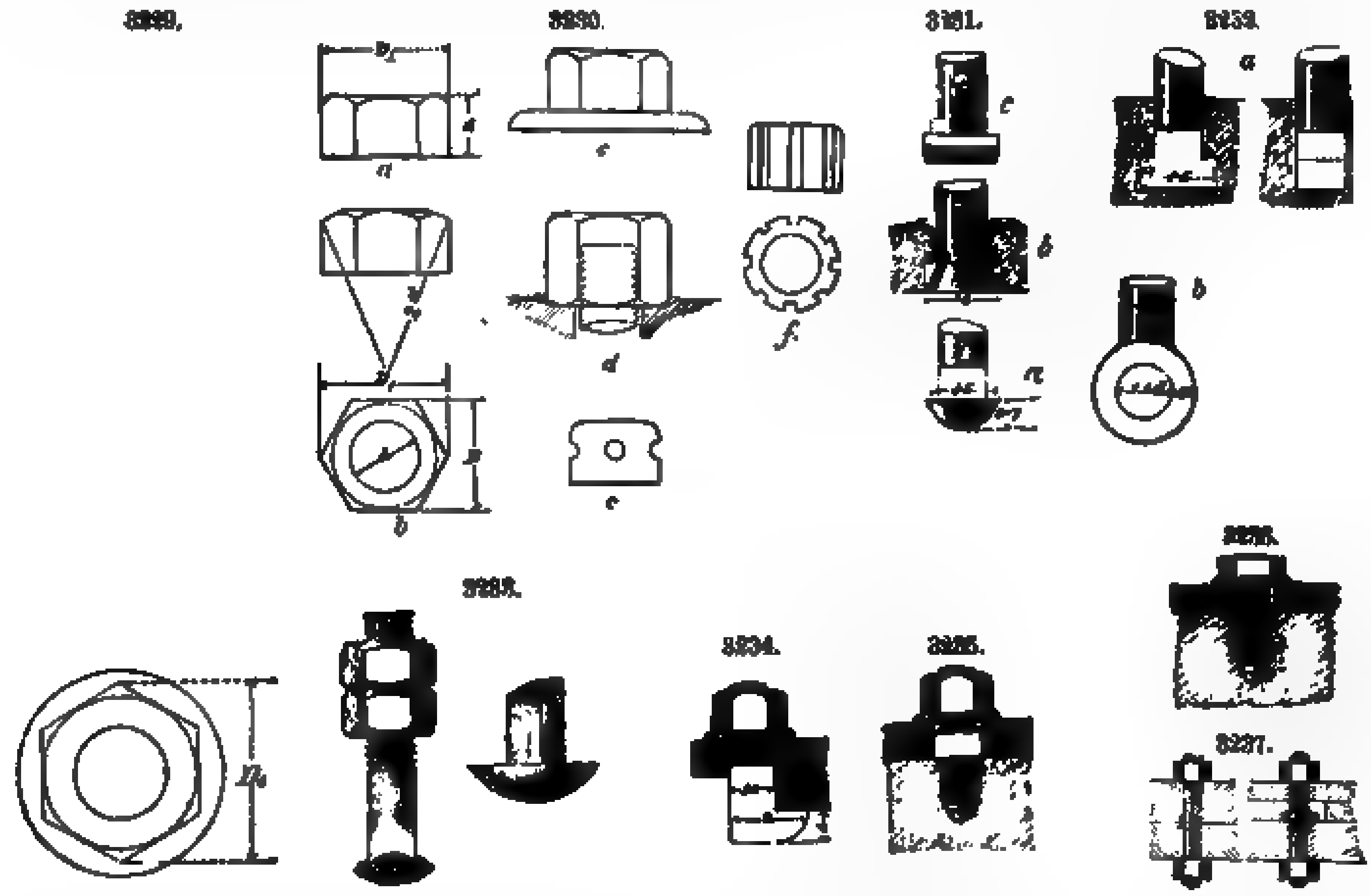
DIAMETER OF BOLT.	Assumed Load due to screwing up.	Effective Strength.	DIAMETER OF BOLT.	Assumed Load due to screwing up.	Effective Strength.	DIAMETER OF BOLT.	Assumed Load due to screwing up.	Effective Strength.
d	$32\ Q$	P_2	d	$32\ Q$	P_2	d	$32\ Q$	P_2
½	1,000	48	1¼	2,700	4,954	2½	5,000	28,570
⅝	1,200	600	1⅜	3,000	6,552	2¾	5,000	36,760
¾	1,500	1,100	1½	3,300	7,810	3	5,000	43,870
⅞	1,800	1,812	1¾	3,600	11,410	3¼	5,000	53,590
1	2,100	2,648	2	4,000	15,790	3½	5,000	63,310
1⅛	2,400	3,567	2¼	4,500	21,480	4	5,000	85,090

Proportions of Bolts and Nuts.—Fig. 3229 shows the most ordinary type of bolt, nut, and washer. The bolt has a square head and a square neck to prevent its rotation while the nut is being screwed

up. The nut is hexagonal and the washer circular. The washer is used when the bolt connects rough castings, and then forms a smooth seat on which the nut turns. The following formulæ give good proportions of nuts, D representing diameter across flats, D_1 diameter across angles, and d diameter of bolts: *For hexagon nuts*—$D = 1.5 + 0.18$; $D_1 = 1.75d + 0.16$ for finished nuts; height $= d$; height of lock-nut $= \frac{d}{2}$. *For square nuts*—$D = 1.5d + 0.18$; $D_1 = 2.12d + 0.25$; height, $\frac{7}{8}d$ to d; length of spanner, $15d$ to $18d$. *Washers*—Thickness, $0.15d$; diameter, $\frac{7}{8}D$. Washers for wood may be $3d$ in diameter and $0.3d$ in thickness.

Forms of Nuts.—Ordinary nuts are chamfered off at an angle of 30° to 45°, as shown at *a*, Fig. 3230; or they are finished with a spherical bevel, struck with a radius of about $2d$, as shown at *b*. Flange nuts, *c*, are used when the hole in which the bolt is placed is considerably larger than the bolt itself. The flange covers and hides the hole. Cap nuts, *d*, are used where leakage along the screw-thread is feared. In the figure, a thin, soft copper washer is shown, which prevents leakage under the nut. Circular nuts, *e*, are occasionally used. They have holes, in which a bar termed a "tommy" is placed, for screwing them up. Sometimes grooves are cut, as shown at *f*. Steel nuts may be used, if great durability is required.

Forms of Bolt-Heads.—In Fig. 3231, *a* is a cup-shaped, *b* a countersink, and *c* a square bolt-head. Rotation of the bolt is prevented in *a* by a square neck, in *b* by a set-screw, and in *c* by a snug forged on the bolt. Fig. 3232 at *a* shows a T-headed bolt in front and side elevation; and at *b* is an eye-bolt. Fig. 3233 is a spherical-headed bolt with a square neck, used sometimes for railway fastenings. In the same figure is a cup-head with a snug forged on the bolt to prevent rotation when the bolt is



screwed up. Fig. 3234 is a hook-bolt, which is used when one piece is too small to have a bolt-hole through it, or when it is objectionable to weaken the piece by a bolt-hole. Fig. 3235 is a stud, which is screwed into one of the connected pieces, and remains in position when the nut is removed. Fig. 3236 is a set-screw, or bolt not requiring a nut. Fig. 3237 shows a nut-headed bolt, or bolt having two loose nuts, instead of a nut and head. The second figure is a similar bolt, with an intermediate head or flange. Fig. 3238 is a bolt leaded into stonework. The tail of the bolt is rectangular, with jagged edges. Fig. 3239 is a fang-bolt, used for attaching ironwork to wood, and especially for attaching rails to sleepers. The fangs of the broad triangular plate which forms the nut bite into the wood, while the bolt is rotated by the head, which bears on the ironwork. The large area of the nut prevents crushing of the wood.

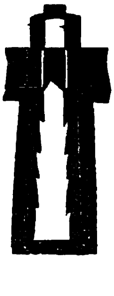
Lock-Nuts are devices intended to prevent the gradual unscrewing of nuts subjected to vibration and frequent changes of load. No nut accurately fits its bolt; a certain amount of play, however minute, always exists. When a nut having play is subjected to vibration, it gradually slacks back. This may to a great extent be prevented by double nuts, as shown in Fig. 3240. One of the nuts is termed a lock-nut, and is usually half as thick as the ordinary nut. When there are two nuts, the whole load may be thrown on the outer nut, which therefore should be the thicker. Another plan is to drill a hole through the top of the bolt above the nut, and drive a split pin or cotter through. Fig. 3241 shows a stop-plate fixed on one side of the nut. In Fig. 3242, the lower part of the nut is turned circular, and fits in a recess in the piece connected by the bolt. A set-screw is tapped through, and bears on the side of the nut. A stop-ring is sometimes used, Fig. 3243, with a set-screw tapped through it. The stop-ring is of brass or wrought iron, and it is prevented from turning by a stop-pin of the same size as the set-screw. Elastic washers have been used as substitutes for

lock-nuts; an example of this device is given in Fig. 3244. When the nut is tightened up, the washer becomes nearly but not quite flat, and its elasticity neutralizes the play of the nut on the bolt.

Fig. 3245 represents the Atwood safety-nut. The bottom part is concave, and the upper portion is slotted as shown. The bearing on the corners at the bottom causes the top to be forced in against the bolt, thus grasping the latter so tightly that all working back is claimed to be prevented.

Bolting of Cast-Iron Plates.—Cast-iron plates are united by bolts; flanges to receive the bolts are

3238



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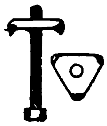

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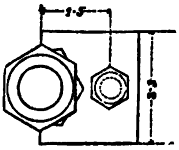

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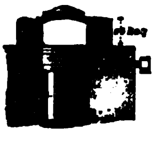

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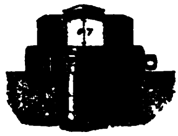

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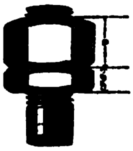

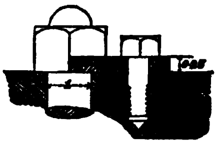

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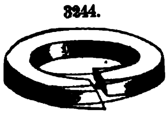

cast on the plates, and these may be external or internal. The flanges are of the same thickness as the plates, or a little thicker. The bolts are never less than three-quarters of an inch in diameter, and the bolt diameter may be equal to the flange thickness. The fitting part of the flanges is often a narrow "chipping strip," which is faced by hand or in the planing machine. Fig. 3246 shows three arrangements of flanges and bolts. Fig. 3247 gives the ordinary proportions of the bolt and flange, which are as follows: bolt diameter, $d = \frac{3}{4}t + \frac{1}{8}$ (but not less than $\frac{3}{4}$ in.); pitch of bolts about $6d$, or

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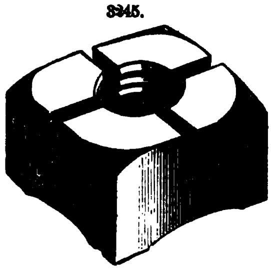

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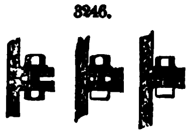

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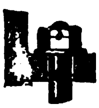

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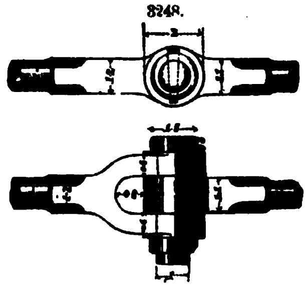


less if necessary for strength; width of chipping strips, $a = \frac{5}{4}t$; width of flange, $b = 2d + \frac{3}{2}t$. t represents thickness of flange.

Joint-Pins and Knuckle-Joints.—A joint-pin is a kind of bolt so placed as to be in shear. Fig. 3248 shows a knuckle-joint. The proportions are empirical. If the joint-pin were subjected to simple shear at two sections, it would be strong enough when its diameter was equal to 0.7 of the diameter of the rods; but the pin wears, and is then subjected to bending, as well as shearing. When there is much motion at the joint, the width of the eyes of the rods and the length of the pin may be increased.

The foregoing is mainly abridged from "Elements of Machine Design," Unwin, New York, 1877.

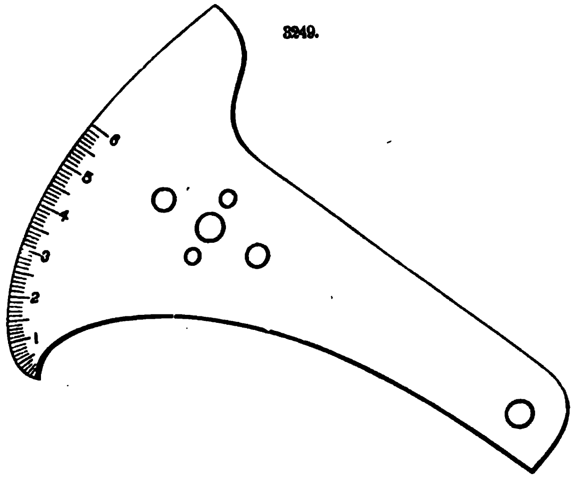
ODONTOGRAPH. An instrument for the laying out of teeth of gear-wheels. A full account of Willis's device for this purpose, with tables, will be found in the former editions of this work. The most improved form of odontograph is that of Prof. S. W. Robinson. This is claimed to give tooth-curves much more exact than can be produced by Willis's system. For a description of the instrument, see "Van Nostrand's Science Series," No. XXIV. The leading propositions of the instrument are: 1. That it give a curve of rapidly changing curvature, having the closest possible osculation with the epicycloid, and at the same time be of general application. 2. That the curve for a tooth-face given by the instrument be normal to a tangent-line to the pitch-circle at the middle of a tooth. 3. That this curve intersect the addendum circle precisely where the epicycloidal curve proper to the tooth in question does.

The curve adopted, as conforming most closely in general with limited initial portions of the epicycloid, is the *logarithmic spiral*. This curve appears to possess the highest degree of adaptation, because of its uniform rate of change of curvature, and also because this rate can be assumed at pleasure. These points follow from the fact that limited portions falling within a given angle at the pole are similar figures. Furthermore, the analytical relation of this spiral to the problem is simple.

The odontograph is shown reduced in Fig. 3249. Its capacity is extended to any degree by simply prolonging the curved edges. It should be made of metal, because it is intended that the instrument, when desired, may be used directly for a scribe-templet, in which use it will be subject to wear

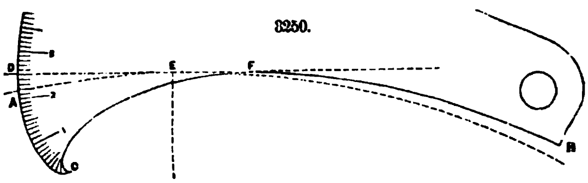
from the passes of the scribe. It has several holes countersunk on both sides as shown, so that it may be attached by wood-screws, or by bolts expressly prepared, to any convenient wooden rod, in such a manner that when the rod swings around a centre-pin to the wheel all the faces of the teeth may be described directly from the instrument itself. The desired result is thus obtained directly without intervening centre-points and dividers. In this manner the odontograph becomes a general or ready-made templet, and equally valuable for guiding the draughtsman's right-line pen or the pattern-maker's steel scribe.

3249.



To place the instrument in position for drawing a tooth-face, a table is used which should accompany the instrument. From this table a value is taken which depends upon the diameters of the pair of wheels, and the number of teeth in the wheel for which the teeth are sought. This tabular value, when multiplied by the pitch, is to be found on the graduated edge $A\ D\ B$, Fig. 3250, of the odontograph. This done, draw the tangent $D\ E\ F$ to the pitch-line at the middle point E of a tooth, and lay off the half thickness $E\ D$ of tooth on either the tangent-line or pitch-line. Then place the graduated edge of the odontograph at D, and in such position that the number and division of scale found as above shall come precisely on the tangent-line at D. Also get the curved edge, $H\ F\ C$, so that the curve will just lie tangent to the tangent-line, as at F. Then all is ready for tracing the curve for the tooth-face from the pitch-line through D toward B as far as needed. By turning the instrument, which is graduated on both sides, over, and doing likewise, we get the opposite face of the same tooth. Then we have simply to draw the radial flanks, when the tooth becomes fully delineated, with the exception of limiting the point and root. Clearance curves may also be struck in, if desired, as in any other case. Of course, when the setting of the instrument is once made, it may be mounted upon a rod, as and for the purpose described above, for drawing all the teeth.

3250.



The curve which this instrument gives will closely represent the initial portions of the hypocycloid, cycloid, and involute, as well as the epicycloid, as far as required for a tooth-face; and hence the instrument is adapted for tracing teeth of these various forms, including the rack-and-pinion, internal-gearing, and involute teeth. For the latter form of teeth the tables become very simple.

OIL, LUBRICATING. See Lubricants.

OIL-CAR. See Railroad Cars.

OIL-CUP. See Lubricators.

OILSTONES. The best qualities of oilstone in the United States are obtained from the novaculite or "whetstone" rock of Arkansas, which is of uniform hardness and somewhat porous, though free from metallic particles. According to Prof. David Dale Owen, chemical analysis of this rock shows the following composition in 100 parts: Silica, 98; alumina, .80; potash, .60; soda, .50; lime, magnesia, hydric fluoride, water, .10. The best variety comes from the vicinity of Hot Springs, and two qualities are recognized, the finer being known as Arkansas stone and the coarser as Washita stone. Arkansas stone is the harder, and resembles white marble. It is seldom found in mass of more than 8 in. in length free from flaws, and it is frequently traversed by thin quartz veins. Where these veins occur the stone must be cut to avoid them, as the material itself, being softer than the quartz, is worn away more rapidly, leaving the quartz projecting above the surface, and hence liable to destroy any cutting edge which may strike it. Washita stone is softer and more porous; it is found in large masses, and seldom contains quartz.

The method of cutting and polishing oilstones, as practised by Messrs. Boyd & Chase of New York, is described in the *Scientific American Supplement*, No. 19. Gangs of saws, each gang requiring some 4 horse-power, cut about 1,000 lbs. of Washita stone per day, and about 60 lbs. of Arkansas stone. The fragments of rock are packed upon the bed of the saw-frame. The saws have a reciprocating motion, and rise at the end of every stroke. The sand and water which are thrown upon the saws then flow down between the saw-edges and the stone beneath. The saws are of soft iron; and when they descend at the beginning of the next stroke, the sand is imbedded in the metal and cuts the stone as the saws move. After being sawed into slabs, the stones are piled under another gang of saws, by which they are cut into proper widths. Their ends are then squared in such a manner as to

avoid flaws and quartz veins. To cut beveled surfaces, the slab is held in an inclined position under the saw by means of plaster of Paris. Lastly, the stones are finished on a large horizontal cast-iron wheel or revolving table, covered with sand and water. The workman presses the stone upon the wheel, which revolves with great velocity and polishes the stone by means of the sand. The machine employed to cut wheel-stones has a shaft the lower end of which is shaped like a gouge-chisel, and cuts the core. The periphery of the wheel is cut by a soft iron, bent to form an arc of the circle it describes, and its corner rounded to permit the sand to flow under. The wheel-stones usually range from 1 in. to 3 in. in diameter. So rare is a large piece of Arkansas rock without flaw, that the cost of a wheel 9 in. in diameter would reach several hundred dollars. Mr. Chase has employed several methods of sawing with diamonds, but he eventually found their use inexpedient. The diamond cuts as much in 20 minutes as the sand can in a day; but so wonderful is the abrading property of this stone, that even diamond points are worn smooth after a few minutes' use. So great is the necessary strain that the strongest saws set with diamonds double up, and the diamonds are frequently forced from their settings or broken. The excellence of the Arkansas and Washita stones is attested by the number exported to all parts of Europe. Their shapes and uses are quite varied. Stone files are made pointed, knife-shaped, cylindrical, and in the shape of triangular prisms, for dentists, jewelers, and watchmakers; also, stones to sharpen surgical, mathematical, and engravers' instruments, and for penknives, needles, and all kinds of wood-working tools.

Manner of using Oilstones.—Oilstones are chiefly employed for smoothing down the asperities left by the grindstone upon sharp edges. Two stones are usually needed, one for roughing and the other for finishing. In addition to these a number of slips of stone are necessary, some being flat, others half round and flat, with round edges, their uses being for gouges and other tools in which the cutting edges are hollow or curved. The general oilstone should be kept with a flat face, otherwise it will be impossible properly to set plane-blades, firmer and paring chisels, and other similar tools, upon it. With this object in view, the workman should set small tools upon the ends, so as to prevent the stone from becoming hollow in the middle. When it becomes necessary to grind the face of the oilstone, it may be done upon the grindstone; but a better plan is to take a flat board and liberally supply it with clean sand and water, and then grind the oilstone on it by hand, making the face a little rounding in its length by easing it off at each end, but leaving it flat across the face, by which means it will last longer without regrinding. There are some stones which are used with water instead of oil; they do not cut, as a rule, very freely, but the finer grades of them will cut unusually smooth; these are the descriptions used by the Japanese workmen, who use two stones, one to rough-cut, which cuts very freely, the other to finish, which seems to grip the metal firmly, rendering it easy to keep the tool at the necessary angle and bevel, while at the same time it cuts very finely indeed.

8251.

The operation of using the oilstone is termed "setting" an edge. Chisels and other straight-faced tools when being set are best held in such a manner that the direction of the motion of the hands is nearly but not quite at right angles to the line of the cutting edges, as may be seen in the operation of setting a plane-iron as shown in Fig. 8251. But in the case of carpenters' gouges, it is preferable to set the edge by moving it in the direction of its length. For this purpose the right hand, in which the tool is grasped, is held considerably to one side of the stone, every portion of the edge being then brought into contact with its surface at each forward or backward stroke by means of a similar wrist-motion to that given in grinding it. J. R. (in part).

OIL-TESTER. See Lubricants.

OIL-WELLS. See Well-Boring.

OLEOMARGARINE. See Butter, Artificial.

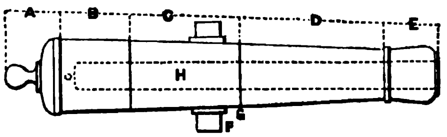
OPENER. See Cotton-spinning Machinery.

ORDNANCE, CONSTRUCTION OF. The term ordnance includes artillery of all kinds in its most comprehensive signification. Within the last twenty years the art of using a gun and developing its power has been virtually transformed by the aid of scientific research and mechanical skill. This process of evolution is in active progress. The production of a gun more powerful than any hitherto known serves but as a challenge to the manufacture of armor capable of resisting the shot from that weapon; and success in this last involves efforts toward the construction of cannon of still greater penetrating energy. With the enormously heavy guns of modern times, new discoveries in the strength of gun-metals, in the art of making projectiles, in the nature of explosives, and in the resistance of various forms of armor, are made. These in turn react upon principles of gun construction previously deemed settled, and produce modifications in them; and thus advancement is accomplished by the light of experiment alone.

Theory of Construction.—*Constituent Parts.*—Cannon are classified as guns, howitzers, and mortars, or as field, mountain, prairie, siege, and seacoast cannon. Fig. 8252 represents an old form of cannon, which exhibits clearly the five principal parts into which nearly all guns are regarded as divided. These are the breech, *A*; the first reënforce, *B*; the second reënforce, *C*; the chase, *D*; and the swell of the muzzle, *E*. The breech is the solid part of the piece in the prolongation of the axis; its length should be from one to one and a quarter time the diameter of the bore, *H*. The first reënforce extends from the base-ring to the seat of the ball, and is the thickest part of the

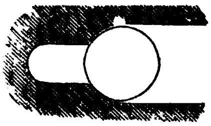
piece, for the reason that the pressure of the gas is found by experience and calculation to be the greatest before the ball has moved far from its place. The second reënforce is that portion of the piece to which the trunnions are attached, and extends from the first reënforce to the chase; it is made thicker than is necessary to resist the pressure of the gas, in order to serve as a proper support for the trunnions and to compensate for defects likely to appear in all castings of irregular shapes. The chase extends from the end of the second reënforce to the muzzle, or to the swell of the muzzle, which is now generally omitted from large cannon. Trunnions, *F*, are cylindrical arms attached to the sides of cannon for the purpose of supporting them upon their carriages, and permitting them to be elevated and depressed in action. On the supposition that the strain upon the trunnions is proportional to the weight of the charge, it is laid down as a rule that the diameter of a gun's trunnions should be equal to the diameter of its bore, and of a howitzer's equal to the diameter of its chamber. The axis of the trunnions is placed in the same plane with the axis of the piece in all the cannon of the United States service; and in this position the force of the charge is communicated to the trunnions directly, without producing any other than the inevitable strain on the carriage, and without checking the recoil. Were the axis of the trunnions above or below that of the piece, the force of the discharge would act to turn the piece slightly upward or downward, producing unequal strains. In many cannon the axis of the trunnions passes also through the centre of gravity of the piece. This arrangement was introduced by Gen. Rodman, who has shown that cannon constructed in this way may be fired with accuracy, and, although easily moved, do not when fired sensibly change their position before the projectile leaves the bore.

3252.



The interior of cannon may be divided into three distinct parts: the vent, or channel by which fire is communicated to the charge; the chamber, or seat of the charge; and the bore, or that part of the cylinder passed over by the projectile. The size of the vent should be as small as possible, in order to diminish the escape of the gas, and the erosion of the metal which results from it; and experiment shows that the interior orifice of the vent should be placed at a distance from the bottom of the chamber equal to a quarter of its diameter, or at the junction of the sides of the chamber with the curve of the bottom. The form of the chamber, or seat of the charge, has an effect upon the force of the gunpowder, as well as upon the strength of the piece to resist it; and experience has shown that its length should in general be equal to its diameter, and its surface should be as small as possible compared with its volume. The charges with which solid projectiles are fired being generally greater than one-sixth of their weight, the cartridge occupies a space the length of which is greater than the diameter; the form of the seat of the charge is therefore simply the bore prolonged. This arrangement reduces the length of the charge so that its inflammation is as complete as possible before the projectile begins to move. To give additional strength to the breech, the bottom of the bore is generally rounded into an arc of a circle, but is sometimes hemispherical, tangent

3253.



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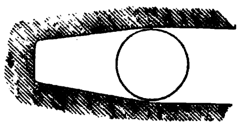

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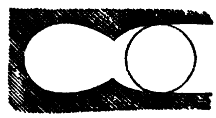


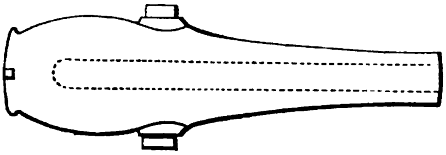
to the surface of the bore. All cannon of the newest models have the bottom of the bore finished as a semi-ellipsoid, this form being thought to give greater strength than the hemisphere. The accompanying figures illustrate the various forms of chambers in use. Fig. 8253 represents a cylindrical chamber; Fig. 3254, a conical chamber; and Fig. 8255, a spherical chamber.

Length of Bore.—Originally, when mealed powder was habitually used, it was believed that the longest pieces gave the greatest range. In accordance with this idea, culverins were made of great length, and were only shortened after repeated experiments showing that the range increased at each reduction in length. The length of the bore has an important effect upon the velocity and range of the ball. This will be clearly seen by a consideration of the forces which accelerate and retard its movements. The accelerating force is due to the expansive effort of the burning powder, which is greatest when the grains are completely converted into gas, which in turn depends upon the size of the charge and the size and constitution of the grains. The retarding forces are the friction of the projectile against the sides of the bore, the shocks of the projectile striking against the sides of the bore, and the resistance offered by the column of air in front of the projectile. As the accelerating force of the charge increases up to a certain point, or till the combustion is completed, and rapidly diminishes as the space in rear of the projectile increases, and as the retarding forces are always opposed to its motion, it follows that there is a point where these forces would become equal, and the projectile move with its greatest velocity; it also follows that after the projectile passes this point its velocity decreases, until it is finally brought to a state of rest, which would be the case in a cannon of great length. Experiments made by Maj. Mordecai show that the velocity increases with the length of bore up to 25 calibres, but that the gain beyond 16 calibres gives an increase of only one-eighteenth to the effect of a 4-lb. charge. Taking the calibre as the unit of measure, it has been found by experience that the length of bore is greater for small arms which fire leaden bullets than for guns which fire iron shot, and greater again for the latter than for howitzers and mortars which fire hollow projectiles. In the earlier days of artillery, when dust instead of grained powder was

used, the weight of the charge was equal to that of the projectile; but it is now admitted that a charge of powder equal to one-fourth of the weight of the projectile, and a bore of 18 calibres long, are the most favorable combination that can be made in smooth-bored cannon, to obtain the greatest range with the least strain upon the piece and its carriage.

Strains.—The kinds of strain to which a cannon is subjected are: 1. A tangential strain, tending to split the gun open longitudinally, and similar in its action to the force which bursts the hoops of a barrel; 2. A longitudinal strain, tending to pull the gun apart in the direction of its length, which tendency is a maximum at the bottom of the bore, and diminishes to zero at the muzzle; 3. A strain of compression exerted from the axis outward, tending to crush the truncated wedges of which a unit of length of the gun may be supposed to consist, and to diminish the thickness of the metal to which it is applied; and 4. A transverse strain, tending to break transversely the staves of which the gun may be supposed to consist, and similar in its action to the force which breaks the staves of a barrel.

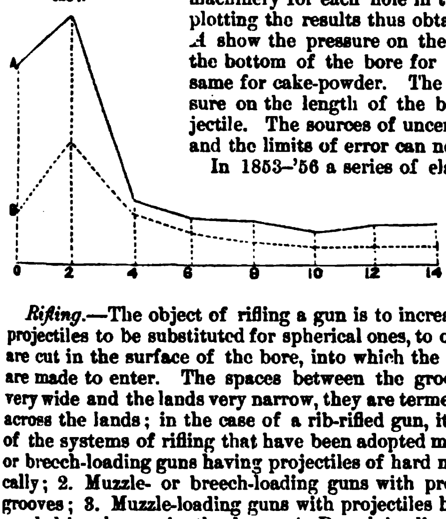
3256



A formula embodying the strains, the pressure of the gas, and all other elements entering into the question, was deduced by Gen. Rodman from a series of original experiments. Its solution for particular cases gives a series of curved lines, a specimen of which is shown in Fig. 3256, which represents a Rodman gun.

Testing Guns.—Various methods have been resorted to for determining the pressure of the gases throughout the bore, and deducing therefrom the proper exterior form for different kinds of cannon, and also of ascertaining the safety of the gun. Among the most successful of these is a modification of a plan first used by Col. Bomford in 1841, and subsequently improved by Gen. Rodman. It consists in boring a series of small holes through the sides of a cannon at right angles to its axis, at intervals of one calibre, and loading them with steel balls, which are projected by the force of the charge into a ballistic pendulum. The pressure at the various points is calculated from the velocity given to the balls. Gen. Rodman's modification consists in substituting for the bullets a steel punch which is pressed by the force of the gases into a piece of soft copper. The weight necessary to make an equal indentation by the same punch in the same copper is then obtained by machinery for each hole in the side of the gun, and a curve is constructed by plotting the results thus obtained, as in Fig. 3257. The ordinates of the curve *A* show the pressure on the bore at intervals of two calibres, commencing at the bottom of the bore for grain-powder; and those of the curve *B* show the same for cake-powder. The latter produced only about one-half the mean pressure on the length of the bore, and gave nearly the same velocity to the projectile. The sources of uncertainty in this form of gauge, however, are various, and the limits of error can never be predetermined.

3257.



In 1853-'56 a series of elaborate experiments was made at the Washington Arsenal, upon an apparatus devised by Dr. W. E. Woodbridge, termed a "piezometer" or pressure-measurer. Renewed attention has lately (1879) been directed to these trials, and a full record of them has been published in "Ordnance Notes, No. XC.," dated Nov. 20, 1878.

Rifling.—The object of rifling a gun is to increase its accuracy of fire, and, by enabling elongated projectiles to be substituted for spherical ones, to obtain longer ranges. To rifle a gun, spiral grooves are cut in the surface of the bore, into which the projections or soft-metal coating of the projectile are made to enter. The spaces between the grooves are called "lands." Where the grooves are very wide and the lands very narrow, they are termed "ribs." The calibre of a rifled gun is measured across the lands; in the case of a rib-rifled gun, it is measured to the bottom of the grooves. Most of the systems of rifling that have been adopted may be divided into the following classes: 1. Muzzle- or breech-loading guns having projectiles of hard metal, fitting the peculiar form of the bore mechanically; 2. Muzzle- or breech-loading guns with projectiles having soft-metal studs or ribs to fit the grooves; 3. Muzzle-loading guns with projectiles having a soft-metal envelope or cup, which is expanded by the gas in the bore; 4. Breech-loading guns with projectiles having a soft-metal coating larger in diameter than the bore, but which is compressed by the gas into the form of the bore.

To the first class belong the Whitworth, Vavasseur, Scott, and Lancaster systems. The Whitworth gun has a hexagonal spiral bore, the corners of which are rounded off. The form of the bore is not, however, strictly hexagonal. The interior of each gun is first bored out cylindrically, and when the rifling is completed a small portion of the original cylindrical bore is retained along the centre of each of the sides of the hexagonal bore, and the other parts of each side recede or incline outward toward the rounded angles; hence the diameter of the hexagonal bore is greatest at the rounded angles. In Vavasseur's system, the rotation is given by means of raised ribs in the bore, while the projectile itself has corresponding grooves cut along its cylindrical surface. The ribs are three in number, and there are no sharp angles either in the projectile or the bore of the piece. The twist is one turn in 30 calibres for all sizes. In Scott's system, the bore is rifled with narrow shallow grooves, deeper on the driving than on the loading side. The projectile is one iron casting, having ribs almost triangular in section, extending the whole length of the cylindrical body, and set to the angle of the rifling. Lancaster's system may be described as that of the usual circular bore with two wide grooves, each about one-third the circumference in width, the shoulders of the grooves being shaved off so as to form an ellipse. The cross-section of the bore is oval, only a trace of the original

bore being left at the minor axis. This system has not been successful in competition with other systems.

To the second class of rifling systems belong the Woolwich or French rifling and the shunt system. The Woolwich system is a modification of the French, and consists of deep broad grooves, each of which receives two soft-metal circular studs. The grooves are three or more in number, according to the calibre of the piece. The shunt system is one of Armstrong's methods. Its peculiarity is that the depth and width of the grooves vary at different parts, the object aimed at being to provide a deep groove for the studs of the projectile to travel down when the gun is being loaded, and a shallow groove through which they must pass when the gun is fired, so that the projectile may be gripped and perfectly centred on leaving the muzzle. This is obtained by making one side of the groove (the driving side) shallow near the muzzle.

The third class of rifling is represented by the Parrott system. In this the grooves and lands are of equal width, the former being one-tenth inch deep for all calibres. The bottom corners of the grooves are rounded to facilitate cleaning and to avoid sharp angles. The projectiles are recessed around the corner of the base to receive a brass ring, which is expanded into the grooves of the gun by the explosion of the powder.

The fourth class of rifling is illustrated by the German system or Krupp's method. In this system, the grooves are usually 30 in number for all calibres, and are quite shallow. The sides are radial, forming sharp angles with the bore. The rifling has a uniform twist of one turn in 25 ft. The grooves are wider at the bottom of the bore than at the muzzle, so that the compression of the lead-coated projectile is gradual, and less force is expended in changing the shape of the projectile. This change of shape is effected by making the whole groove of the same size as at the muzzle, and then cutting away gradually on the loading edge of the groove. Of course, as the twist is uniform, the driving side of the groove cannot vary.

Forms of Cannon.—Muzzle-Loading Smooth-Bore.—The construction of smooth-bore guns is explained under Ordnance, Manufacture of. The principal forms are the Dahlgren and the Rodman.

The Dahlgren Gun is represented in Fig. 3258, which shows the form of the navy 15-inch, such as

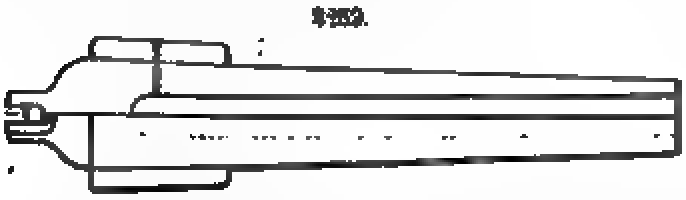
3258.

is commonly used in monitor turrets. The principal data regarding these guns will be found in the table on page 490. The same table exhibits the dimensions, etc., of Rodman guns. The general form is shown in Fig. 3258.

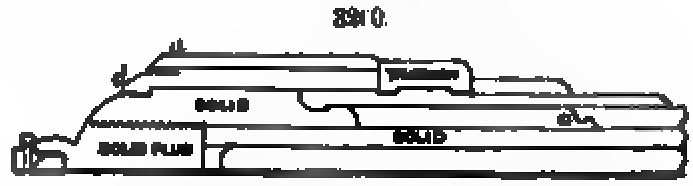
Muzzle-Loading Rifles.—*The Parrott Gun*, Fig. 3259.—This is an American cannon, hitherto fabricated exclusively by the inventor, the late Captain Parrott of the West Point Foundry. Its peculiarity consists in the fact that the gun is a cast-iron piece, strengthened by shrinking a coiled hoop of wrought iron over that portion of the body which surrounds the charge. None of these guns have been manufactured since 1865.

The Armstrong Gun.—To Sir William Armstrong is due the credit of employing wrought-iron coils shrunk together to form the gun. His principles are: (1) to arrange the fibre of the iron in the several parts of the gun so as best to resist the strain to which they are respectively exposed; and (2) to shrink the successive parts of the gun together so that not only is cohesion throughout the

3259.



3260.



mass insured, but the tension may be so regulated that the outer coils shall contribute a fair share to the strength of the gun. A section of this weapon is shown in Fig. 3260. The barrel is made of solid steel ingot bored out and tempered in oil, by which its brittleness is decreased and tenacity increased. That part of the barrel at and in rear of the trunnions is enveloped by three layers of wrought-iron tubes, not welded at the ends, but hooked to each other by shoulders and recesses. This is accomplished by heating and expanding the end of one tube and slipping it over the shoulder of another, upon which it contracts by cooling. The breech is closed by a cylindrical forged block with a bevel screw-thread cut upon it; this is screwed into the breech-coil and made to bear fairly against the solid end of the steel A tube; this also forms the cascable of the gun, and is called the cascable screw. The first guns constructed by Armstrong were breech-loading, but his system of

fermeture could not be applied to the larger calibres. This principle was therefore abandoned, and the muzzle-loading gun adopted.

A 100-ton gun of the Armstrong type has been constructed for the Italian armored vessel Dandolo, and is represented in a full-page engraving. (See Armor.) The following are the leading particulars and dimensions: Total length over all, 32 ft. 10½ in.; greatest diameter over chamber, 77 in.; diameter at muzzle, 29 in.; diameter at end of trunnion-coil, 45 in.; diameter of bore, 17 in.; length of bore, 30 ft. 6 in.; number of grooves, 27; twist at chamber, 1 in 150 calibres, increasing thence to a point near the muzzle to 1 in 50, after which it is uniform; preponderance, 4 tons; weight of projectile, 2,000 lbs.; powder charge, from 300 lbs. upward. The gun is built with a steel A tube made in two lengths, and of varying thicknesses increased in steps from the muzzle to the chamber. Around the chamber three coils are placed over the A tube as far as the trunnion-coil, where they are reduced to two, and finally to one for rather more than half the total length of the gun. The carriage upon which this monstrous piece of artillery is mounted consists of two blocks on which the trunnions rest, and which are free to slide in guides on the floor of the turret; behind these blocks are placed the hydraulic-brake cylinders, so as to take up the force of the recoil in the simplest and most direct manner. The gun was loaded and worked entirely by hydraulic power, as shown in Fig. 3261. *A* is the gun-platform, *B* the slide on which the gun recoils, *C* the sliding trunnion-blocks carrying the gun, and *D* the recoil-presses. *E E* are the chests containing the valves by which the resistance to recoil is regulated, *F* the elevating press, and *G* the hinged beam through which the elevating press acts on the gun, and upon which the breech of the gun slides in recoiling; *H H* are iron bands connecting the gun with the sliding-block *I*; *K* shows the position of the muzzle of the gun when depressed for loading after recoil; *L* is the projectile on its trolley; *M* the hydraulic telescopic rammer with sponge-head; *N* the chain and press for withdrawing the rammer; and *O* the engine for supplying the hydraulic power. The following table exhibits the results obtained from the trials of the 100-ton gun:

Summary of Experiments with the 100-Ton Gun.

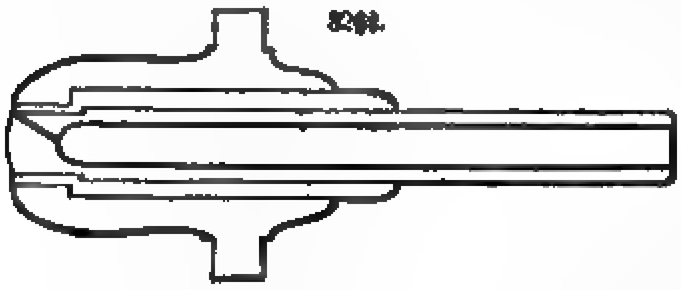
NUMBER OF ROUND.	Weight of Powder Charge.	Weight of Projectile.	Muzzle Velocity in Feet per Second.	Total Energy in Foot-Tons.	Foot-Tons of Energy per Inch of Shot's Circumference.	Foot-Tons of Energy per Pound of Powder.	Mean Pressure in Chamber in Tons per Sq. Inch.	Elevation.	Recoil.
	Lbs.	Lbs.							In.
1	300	2,000	.....	......	......	.....	..	5.00	36
2	300	"	.....	......	......	.....	16	2.00	34
3	300	"	.....	......	......	.....	..	...	....
4	290	"	1,446	28,990	544 05	87.85	..	...	....
5	300	"	.....	......	......	.....	16	1 48	55.5
6	300	"	1,374	27,656	490 10	85.26	16	1	37.5
7	290	"	1,456	29,391	550.30	89.06	20 3	1	44.5
8	319	"	1,429	28,085	525.60	87.58	18.0	1	42.5
9	319	"	.....	......	......	.....	-	6·5	44
10	336	"	.....	......	......	.....	19.4	1.5	46.25
11	340	"	1,475	30,168	561.30	88.70	....	...	.....

The Blakely Gun, Fig. 3262.—In this gun the inner tube or barrel is formed of low steel; the next tube consists of high steel, and is shrunk on the barrel with just sufficient tension to compensate for the difference of elasticity between the two. The outer jacket to which the trunnions are attached is of cast iron, and is put on with only the shrinkage attained by warming it over a fire. The steel tubes are cast hollow and hammered over steel mandrels by steam-hammers, by which process they are elongated about 130 per cent. and the tenacity of the metal at the same time is

increased. They are made to throw 700-lb. projectiles, with a calibre of 12 in., and weigh as much as 40,000 lbs.

The Vavasseur Gun, Fig. 3263.—This gun is manufactured entirely of steel. The inner or A tube is rough-bored, left solid at its breech end, turned down nearly to its finished dimensions, then tempered in oil; after which it is again turned and fitted for the jacket *B*, which is shrunk over the breech end of the A tube; the proper amount being allowed for shrinkage, which amount is carefully ascertained by gauging the surfaces to be joined. The B tube is heated over a pit, the furnace being constructed around it. When sufficiently heated the A tube is quickly lowered into its place by means of a crane, and the whole allowed to cool, the fire being smothered with sand. Any longitudinal movement of these surfaces is prevented by a shoulder abutting. Coiled steel hoops are then shrunk over the chest, and the gun turned for receiving the trunnion-hoop and the remaining front and rear ones. The hoops are short, being from 6 to 8 in. in length, and can therefore be thoroughly worked and more easily and accurately adjusted. The rifling is upon the rib system, 1 turn in 30 calibres, uniform for all sizes of the gun, requiring no studs upon the projectile, giving more bearing surface for it, and rendering the bore less liable to foul.

3262.



The Woolwich Gun, Fig. 3264.—This gun now forms mainly the type used for English armaments, and is built upon the Armstrong principle modified and improved by Mr. Frazer, who reduced the cost of the gun as well as the number of parts. These guns have been constructed of various calibres, viz., 7 in., 8 in., 9 in., 10 in., 11 in., 12 in., 16 in. The last named is known as the 81-ton gun, a description of which will suffice to show the method of construction for all sizes. The interior of the gun was formed by a solid-ended steel tube, weighing 16½ tons, and having no flaws. The material used was entirely crucible steel, being melted in about 240 small crucibles, whose contents were

3263.

run into a large mould. Over the rear end of the steel tube was shrunk a very powerful coil of wrought iron, called the breech-piece. This was made of a single bar, 12 in. thick from inside to outside, hammered, rolled, and coiled—forming a cardinal point in the mode of construction. The cascable was next screwed in, so as to abut firmly against the solid end of the tube, and the B coils were then shrunk on into their places. The ponderous C coil, carrying the trunnions, was made of two coils, one outside the other, and was 18 in. thick. These coils were welded together under the 40-ton hammer. It should be stated that, in order to obtain greater certainty of soundness and ease of manipulation, both the breech-piece and the C coil were made in two pieces, which were welded together, end to end; care being taken that the weld of the breech-piece was not inconveniently near that of the C coil. The shrinkage of the powerful coiled breech-piece caused the bore to contract .020 in., and the compression of the massive outer coil carrying the trunnions was so great that it was transmitted through the breech-piece, and caused a further contraction of .023 in. in the bore. This gun was first constructed with a calibre of 14.5 in., and tested. Its bore was then enlarged,

and further tests were made at 15, and finally at 16 in. When first completed its weight was nearly 82 tons; length of bore, nearly 24 ft.; total length, 27 ft.; number of grooves, 11, spiral, increasing from 0 to 1 in 35 calibres at the muzzle. The inner and trunnion coils are respectively 10.5 in. and 13.5 in. thick. The diameter of the gun at its different lengths is 72 in., 54.5 in., 37.5 in., 32.3 in., and 25 in. After the tests upon the experimental gun modifications were introduced in those subsequently made. The rifling was altered to conform to the polygroove principle, and has a gaining twist commencing at 0 at the front of the powder space and terminating in 1 in 50 at the muzzle. There are 32 grooves 1 in. wide and $\frac{1}{10}$ in. deep with ¼-in. lands. The gun has at present a uniform calibre of 15.5 in. The rate of advance of the rifling was arranged so that the curve of resistance

given by it approximately follows the curve of pressures afforded by the explosion of the powder-charge during the passage of the projectile through the bore of the gun. The forces at work within the gun are thus practically balanced, the moment of greatest resistance of the shot being coincident with that of the greatest force of the powder.

The Whitworth Gun.—This gun was invented by Sir Joseph Whitworth, and is manufactured of homogeneous iron or of steel, the smaller calibres being forged solid, and the larger ones built up. The 7-inch Whitworth is constructed of a central steel tube, covered by a second tube extending its entire length, over which hoops or jackets of steel, cast hollow and hammered out over a steel mandrel, are shrunk. The hoop for the trunnions is shrunk on separately. The inner jacket laps the rear of the tubes, and is screw-tapped; the outer jacket is fitted in the same manner, and the rear end of the tube is also tapped. Into these fit the breech-plugs, which have three corresponding shoulders made to enter the tapping in the tube and outer and inner jackets. The vent is through the breech-plug and in prolongation of the axis of the bore. The rifling, as has already been explained, is radically different from that of other guns, the motion being given by spiral hexagonal surfaces, requiring the projectile to be fitted with corresponding exterior surfaces. This method admits of the more rapid twist which is necessary, together with a higher initial velocity, than with the rib or groove rifling; this necessitates greater strain, but increases range and admits of greater accuracy. The gun was designed for use of heavier charges of powder and longer projectiles than used with other guns. To make the gun endure the strain occasioned by the use of high charges and long projectiles, Sir Joseph Whitworth now manufactures his gun of a superior steel known as the "Whitworth metal." This metal is compressed while in its molten state by applying a heavy pressure, thus increasing its density and tenacity.

II. Breech-Loading Rifles.—England has adopted the muzzle-loading system. France, Germany, Russia, Austria, Italy, Turkey, and Sweden adhere to breech-loaders. Among the chief advantages which breech-loading is claimed to possess, as compared with muzzle-loading, are the perfect fitting of the projectile in the bore, the true centering of the shot, the quicker and more convenient serving of the gun, and the greater security to the gunners, and, as the consequence of these advantages in combination with a suitable class of rifling with uniform twist, far greater endurance of the gun, higher initial velocity of the projectile, increased accuracy, and better powers of penetration.

The Krupp Gun.—The guns constructed by Mr. Friedrich Krupp at Essen, Prussia, are built up by shrinking hoops of steel over a central tube with initial tension. In large calibres the layers of

3265.

hoops are double. Fig. 3265 exhibits the gun on its carriage, and the construction of the piece is shown in Fig. 3266. R is the breech or bottom piece, A the hooped or middle piece, and C the cone or chase. The breech-piece immediately in rear of the hooped piece contains the wedge-hole H, cutting through at right angles to the axis of the bore. In the base of the breech is the hole L for loading, Fig. 3267; and on the side of this aperture is a hook V, with two slots for the hinges of the loading-box and hooks for the shell-bearer. The hooped piece, diminishing in front by steps toward the chase, has in its rear the protruding end hoop D. The central tube T is very massive, and is forged and turned from a single ingot, losing half its weight in the lathe. The hoops are made with an endless fibre, and are kept from working on the gun by key-rings. The breech-plug is a steel cylindro-prismatic wedge, which slides in a mortise on the breech-piece. In the Krupp, as well as in nearly all modern breech-loading guns, the Broadwell gas-check, Fig. 3268, is used. This consists of a plate H and ring I. The latter is of steel, and fits into a groove at the bottom of the bore close to the wedge mortise. In the face of the breech-block is a circular recess, the diameter of which corresponds with the outside diameter of the ring. In this recess is placed the steel-plate, and against this the ring takes its bearing. The cylindro-prismatic block is moved to and fro by means of two screws. The first of these is a quick-motion screw with several threads upon it. This screw is merely used for running the block easily in and out, and is dispensed with in all calibres less than 8 in., in which handles are attached to the end of the block, which is moved by hand. The second screw is employed for jamming and locking the block, and it works into a large cylindrical nut let into a socket made in the broad end of the large block. A portion of the thread of this

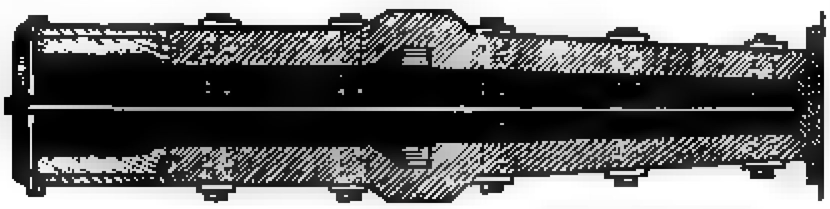
screw is cut away, so that as it is turned the thread may either engage or disengage with the breech of the gun, and the block is thus locked or unlocked. As the block is run home (and this can be done easily without the screws, and by one hand even in the 12-in. gun), the circular plate and the back of the ring come into close contact, and from their form it is impossible that either can be displaced. The rifling is polygroove, and a slightly different twist is given to the sides of the grooves, being 1 turn in 64 ft. 2 in. on one side, and 1 turn in 64 ft. 10 in. on the other, thus making the grooves of diminishing width toward the muzzle, and insuring the tightness of the gas-check. The vent passes through the breech-block, and is in line with the axis of the bore. The chamber is eccentric to the bore, the lower surface being level with the lands, which admits of the projectile moving readily and taking the grooves immediately upon starting from its seat, and preventing gas-escape. These guns have proved superior to all others in endurance, and in trials with the Armstrong gun, at Tegel in Prussia and Steinfeld in Austria, they stood the full test, while the latter failed after comparatively few rounds.

The largest steel gun yet (1879) constructed has been built by Mr. Krupp. It weighs 72 tons, and has a calibre of 15¾ in.; length of the gun 32 ft. 8 in., and of the bore 28 ft. 6 in. The length of bore in the Krupp gun is thus apparent, being 21¾ calibres, as against 18 calibres in the English 81-ton gun. The material of which the Krupp gun is composed is steel throughout. The core of the gun consists of a tube running its entire length, as in the Woolwich gun, but open at the rear, the loading being at the breech instead of the muzzle. The tube of this large weapon being of such great length, it has been made in two portions, the joint being secured in a peculiar manner.

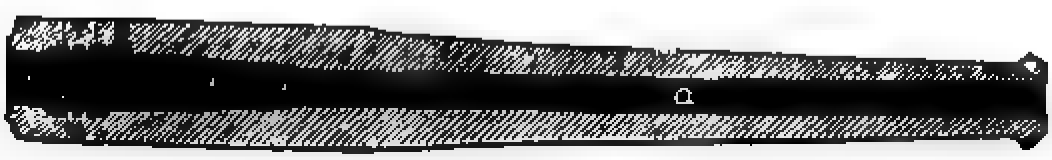
The charge for this monster gun is 385 lbs. of prismatic powder, the projectile being a chilled-iron shell of 1,660 lbs., with a bursting charge of 22 lbs. of powder. The velocity of the projectile as it leaves the muzzle of the gun is calculated to be 500 metres, or 1,640 ft., per second, corresponding to an energy of very nearly 31,000 foot-tons. It is estimated, rather as a matter of curiosity than otherwise, that if the gun were fired with its axis raised to an angle of 43° with the horizon, it would send its projectile to a distance of 15 miles. Great accuracy is also claimed for this weapon, as for all the Krupp breech-loading guns.

The Dean-Uchatius Bronze-Steel Gun.—This gun, constructed on a system devised by Mr. S. D. Dean of Boston, is composed of an alloy of 8 per cent. tin and 92 per cent. copper, cast in a cast-iron mould, in which is placed a cylinder of copper, which by absorbing part of the heat of the molten metal causes rapid chilling of the central portion. A sand-mould is added so as to form a dead-head, in which, owing to the use of the sand, the metal remains in the molten state for a comparatively long

3269.



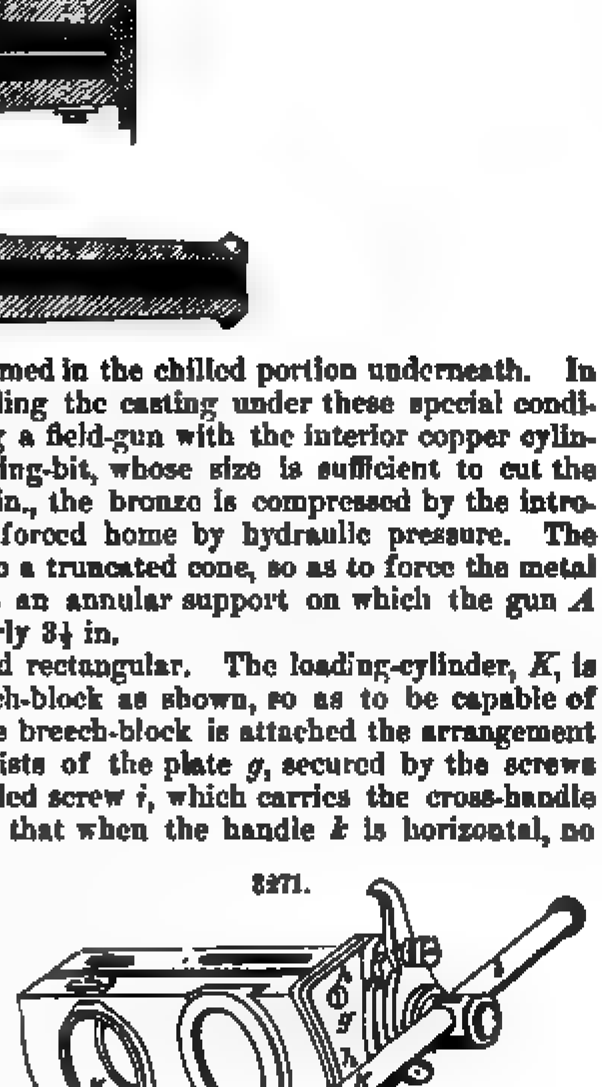
3270.



time, and so fills up any recess that would otherwise be formed in the chilled portion underneath. In short, the dead-head performs the usual function of feeding the casting under these special conditions. In Fig. 3269 is shown the mould ready for casting a field-gun with the interior copper cylinder. The core is eventually entirely removed by the boring-bit, whose size is sufficient to cut the copper entirely away. In a gun whose bore is nearly 3¼ in., the bronze is compressed by the introduction in succession of six steel mandrels, which are forced home by hydraulic pressure. The mandrel, which is well tempered, is formed at the end into a truncated cone, so as to force the metal outward and enlarge the bore. *B*, Fig. 3270, represents an annular support on which the gun *A* rests. After compression the bore has a diameter of nearly 3½ in.

The breech-block, Fig. 3271, is also of bronze-steel, and rectangular. The loading-cylinder, *K*, is also of bronze, cylindrical, and dovetailed into the breech-block as shown, so as to be capable of movement backward and forward. To the left end of the breech-block is attached the arrangement for moving it, and for securing it in position. This consists of the plate *g*, secured by the screws *h h*, through which passes the spindle of the square-threaded screw *i*, which carries the cross-handle *k* at the outer end. The thread of the screw *i* is so cut that when the handle *k* is horizontal, no part of the thread projects beyond the rear face of the block, and the latter can be moved laterally in the slot until this thread comes opposite the female thread cut for its reception in the rear face of the breech-block slot; a half turn of the cross-handle, bringing the same vertical, then causes the screw to bite, and sends the breech-block well home.

3271.



The cannon produced in the manner described are declared to possess all the hardness, homogeneousness, and resistance of steel tubes. The compressed bronze is not more liable to wear than steel, and is much less affected by atmospheric agency. The cost of bronze guns is much less than that of steel, if the value of the old metal be taken into account. One of these new bronze guns has borne several hundred discharges, with the ordinary charge, successively, without the slightest deformity or injury being apparent in any part of the piece.

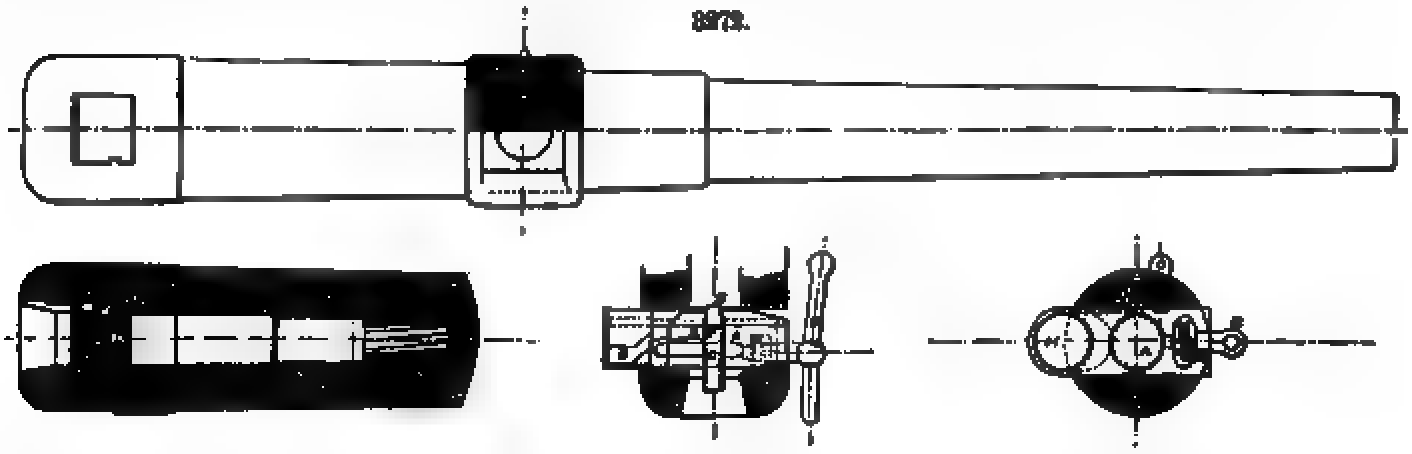
The Hotchkiss Gun.—The construction of this gun is based upon the application of a metallic cartridge, forming the gas-check in the gun, the extraction of the empty cartridge-case being performed automatically by opening the breech. The Hotchkiss cannon of all calibres are made of Whitworth's fluid-compressed steel; those above 2.7 in. bore are jacketed with the same material. Mountain guns of smaller calibres are made of a solid forging, only the trunnion-ring of wrought iron being shrunk on. The breech-loading arrangement consists of a simple prismatic block *A*, Fig. 3272, with a locking-screw *B*, working in a recess in the breech and operated by a lever-handle *C*, with which the block is at the same time drawn out and closed. As a metallic cartridge is used, tightening up the breech is unnecessary, and the breech-block simply forms a backing for the head of the cartridge. In this manner the special gas-check is avoided. The cartridge-extractor *D* is a prismatic piece of steel, forming at its farther end the hook *E*, and working in a recess on the upper part of the breech-slot, and parallel to the bore of the gun. It has on its under side a stud *F*, which works in a groove *G* on the upper side of the breech-block. The stud of the extractor for a time runs in the straight portion of the groove; but as soon as the wedge is so far withdrawn that the loading-hole *H* coincides with the chamber, the stud runs in the inclined part of the groove, and the extractor is consequently moved back quickly, and the empty cartridge-case is in this manner thrown out of the gun

Howitzers are small cannon, usually made shorter and lighter than other guns of similar

calibre, and intended for light charges, comparatively large projectiles, and moderate angles of elevation. Shells are most commonly used as projectiles, and the bore is chambered for the reception of the charge. United States naval howitzers are of bronze, and of the form shown in Fig. 3273. The piece is mounted on its carriage by the bore shown beneath.

Fig. 3274 represents the breech-loading naval howitzer, which is fitted with the French system of breech fermeture. In this system the breech is closed by a screw-plug of cast steel having 14 threads, which is screwed into the rear part of the bore. Were it necessary in firing to screw and unscrew the whole length of the plug at every round, much time would be wasted; but this is obviated by dividing the screw into six parts in the direction of its axis, the threads being removed from

3273.

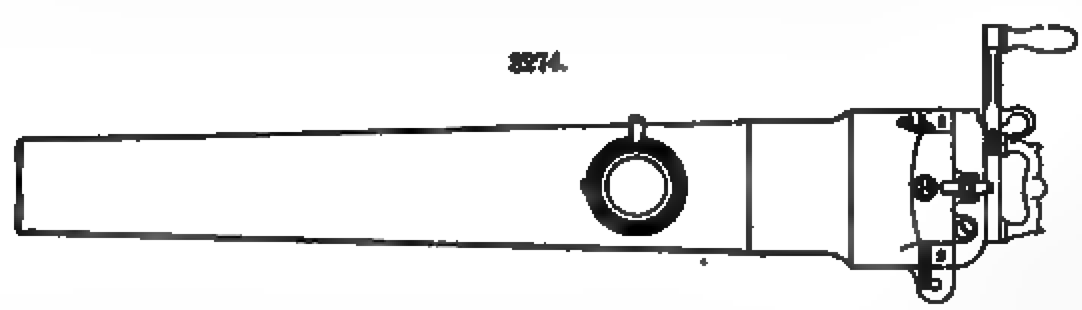


every other one, both from the plug and from the breech of the gun. When the breech is to be closed, the threaded portions of the plug are presented so that they come opposite the smooth parts of the bore-hole. The slug is then pushed in, when a sixth of a turn with the handle brings the screw of both parts together.

Mortars.—A mortar is a piece of ordnance with thick walls and large bore, designed to throw shells at high angles of elevation, usually 45°, thus obtaining a vertical fire. On this account, and for convenience in loading, they are made stronger and shorter than other kinds of ordnance. They are chambered, and small charges of powder are employed, sufficient only to cause the projectile to reach the object. The shell usually contains combustible material for the purpose of firing structures, besides exercising also an additional destructive effect by the velocity of its fall. Mortars are mounted upon a carriage fixed upon a revolving platform, and are used afloat in small vessels especially fitted for them.

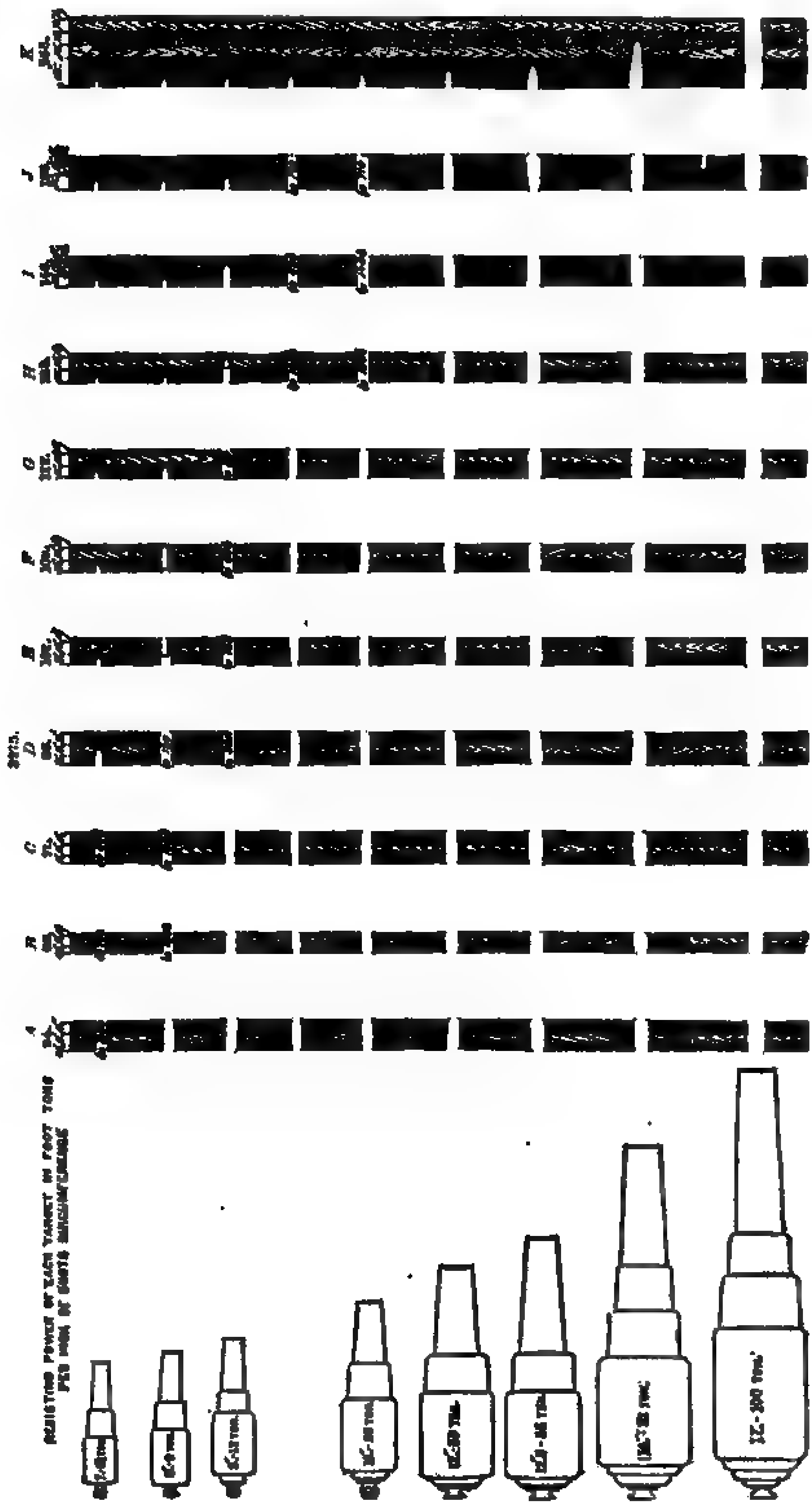
Rifled breech-loading mortars are now used by the principal European nations. Russia has a large number of bronze pieces of this type, fitted with the Krupp method of fermeture, but having the gas-ring of pure copper instead of steel. They are mounted with trunnions upon an iron carriage, consisting simply of two brackets united by a rear transom and several transverse bolts. The elevating gear is a pinion-wheel upon a revolving transverse shaft forward of the trunnions, working in a cogged arc under the piece, and capable of giving it 70° elevation. The Austrians and Prussians also have breech-loading pieces of a similar type, and, though termed mortars, more nearly resembling howitzers of large calibre, designed to be used at high elevations.

3274.



Performances of Heavy Guns.—Fig. 3275, compiled by Major S. C. Lyford, Ordnance Department, U. S. A., shows the penetrative power of projectiles fired from English guns against iron-clad ships of war. Each target represents a certain class of vessels at a distance of 70 yards, except where the range at which projectiles would penetrate is stated. Where the target is shown perforated, but no range is given, it includes all distances up to 2,000 yards. It will be observed that the penetrative power of the German, French, Italian, and Russian guns is practically the same as that of the English, calibre for calibre. The Russian guns have the same power as the Italian 9.4-in., the 15-ton breech-loading rifle, and the 8.2-in., 11-in., and 12-in German breech-loading rifles. The targets represent the armor and backing of different ships, as follows:

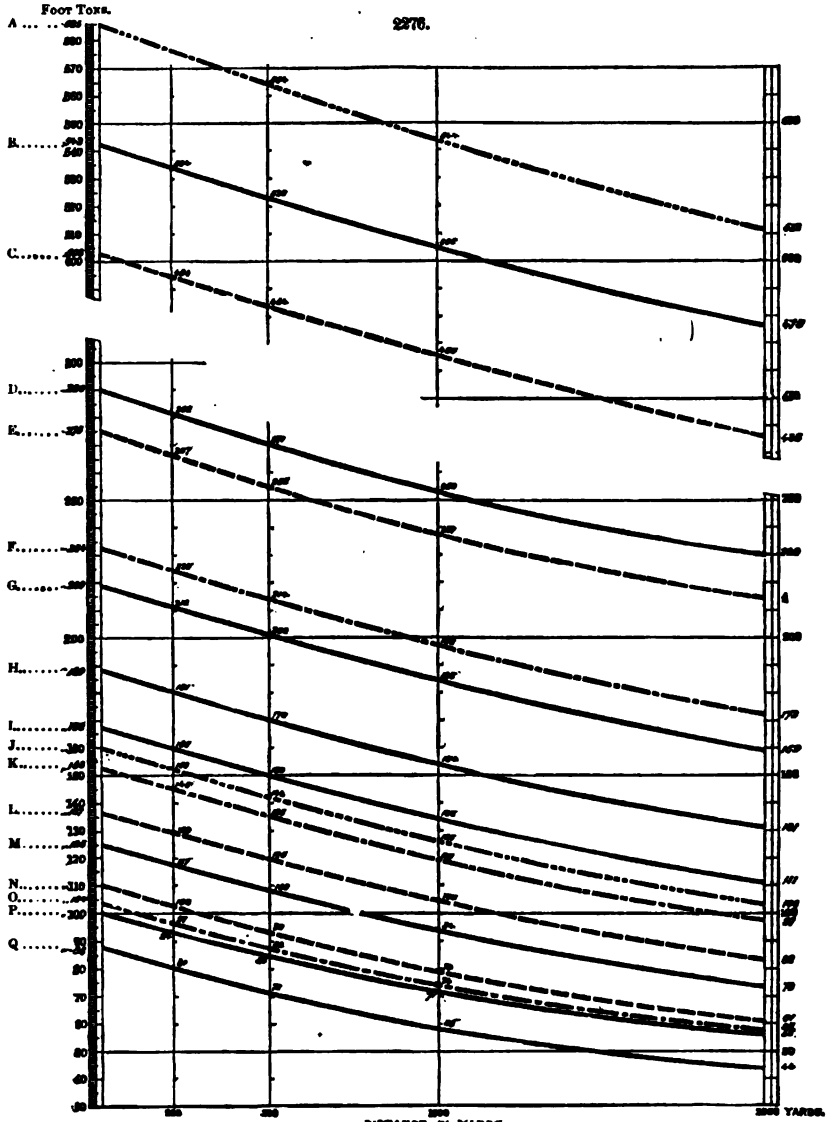
Targets A, B.—American iron-clads, Miantonomoh, Canonicus; English, Minotaur, Resistance, Defence, Black Prince, and Repulse; French, Solferino, Peiho, Embuscade; Russian, Sevastopol, Per-



venetz; Austrian, Kaiser Max, Ferdinand Max; Danish, Rolf Krake; Turkish, Orkanea; Italian, Ancona; Spanish, Saragossa; Brazilian, Herval, Silvado.

Target C—English, Bellerophon, Penelope, Lord Warden; French, Alma, Flandre; Russian, Admiral Greig, General Admiral; German, Hansa; Austrian, Lissa; Turkish, Avni Ilah; Italian, Venezia.

Target D—English, Audacious; French, Ocean, Marengo; Russian, Minin.



A. 100-ton, 17-in., M. L. rifle—Italian.
B. 81-ton, 16-in., M. L. rifle—English.
C. 56½-ton, 14-in., B. L. rifle—Prussian.
D. 38-ton, 12.5-in., M. L. rifle—English.
E. 36-ton, 12-in., B. L. rifle—Prussian.
F. 34½-ton, 12.6-in., B. L. rifle—French.
G. 35-ton, 12-in., M. L. rifle—English.
H. { 25-ton, 11-in., M. L. rifle—English. 22-ton, 10.2-in., B. L. rifle—Prussian. 21-ton, 10.8-in., B. L. rifle—French. }
I. 18-ton, 10-in., M. L. rifle—English.
J. 15-ton, 9.4-in., B. L. rifle—Italian.
K. 14-ton, 9.4-in., B. L. rifle—French.
L. 15-ton, 9.2-in., B. L. rifle—Prussian.
M. 12-ton, 9-in., M. L. rifle—English.
N. 9-ton, 8.2-in., B. L. rifle—Prussian.
O. 7.8-ton, 7.8-in., B. L. rifle—French.
P. 9-ton, 8-in., M. L. rifle—English.
Q. 6½-ton, 7-in., M. L. rifle—English.

Target E—English, Hydra; German, Kaiser Wilhelm; Austrian, Archduke Albert; Danish, Odin.

Target F—French, Friedland; Dutch, Duffel Tiger; Turkish, Fethi Bulend.

Target G—French, Cerbère; Italian, Custozza; Chilian, Almirante Cochrane.

Target H—German, Kaiser; Brazilian, Independencia.

Target I—English, Hercules, Hotspur; Russian, Novgorod.

Target J—English, Devastation; French, Redoutable, Richelieu, Tonnerre; Russian, Peter the Great; Brazilian, Garavi.

Target K—English, Inflexible; Italian, Duilio.

The diagram, Fig. 3276, also compiled by Major Lyford, exhibits the penetrating energy, in foot-tons per inch of shot's circumference, of foreign ordnance, at ranges of from 70 to 2,000 yards from muzzle of the gun. Guns are indicated as follows: English, ———— ; French, ———— ; German and Russian, ———— ; Italian, ————. The Russian guns are represented in power by the 12-in., 11-in., 9.2-in., and 8.2-in. Prussian breech-loading rifles.

*Table showing Weight, Dimensions, etc., of Ordnance of the United States Land Service.**
Standard and Retained Calibres.

NAME OF PIECE.	Material.	Weight.	Extreme Length.	No. of Grooves.	Calibre.	Charge of Powder.	PROJECTILES.†		Initial Velocity.	Range in yards.
							Weight of Shot.	Weight of Shell empty.		
SEA-COAST PIECES.										
Guns.		Lbs.	In.		In.	Lbs.	Lbs.	Lbs.	Feet.	
Rifle (Model 1878).....	Cast iron, wr't-iron lined.	89,600	262.8	21	12	110	700	....	1,896	....
Rifle (Model 1870).....	"	82,878	240	21	12	100	600	....	1,810	....
Rifle.................	"	40,681	180	17	10	80	400	860	1,480	....
Rifle (Converted).....	Cast iron, with wr't-iron tube.	16,160	186.66	15	8	85	180	150	1,414	....
Rifle (Parrott, 300-pdr)	Cast iron, with wr't-iron jacket.	26,500	175.1	15	10	25	300	250	....	4,290
Rifle (Parrott, 200-pdr)	"	16,800	168	11	8	16	200	150	....	4,272
Rifle (Parrott, 100-pdr)	"	9,700	154.25	9	6.4	10	100	80–100	1,222–1,365	8,458
Rifle (Banded, 42-pdr)	Cast iron.	......	129.4	15	7	...	....	....		
Rifle (Banded, 32-pdr)	"	......	125.20	18	6.4	...	....	....	....	...
Smooth-bore.........	"	115,200	243.5	..	20	200	1,080	725	....	....
Smooth-bore (Model 1878)............	"	......	......	..	15	...	450	330	....	8,001
Smooth-bore (Model 1861)............	"	49,099	190	..	15	125	450	330	1,735	...
Smooth-bore.........	"	38,500	177.6125	..	13	70	283–300	224	1,597	....
Smooth-bore.........	"	15,059	136.66	..	10	25	128	100	1,500	....
Smooth-bore.........	"	8,490	123.3	..	8	15	68	48	....	....
Mortars.										
Smooth-bore.........	Cast iron.	38,675	75	..	15	...	....	330	....	....
Smooth-bore.........	"	17,250	56.5	..	13	20	....	216	....	4,686
Smooth-bore.........	"	7,300	49.25	..	10	12	....	101.67	....	4,536
SIEGE PIECES.										
Guns.										
Rifle.................	Cast iron.	3,450	133	9	4.5	7	35	25	1,420	....
Rifle (Parrott, 30-pdr.)	Cast iron, with wr't-iron jacket.	4,200	132.75	5	4.2	...	25–30	29	1,298	6,700
Howitzers.										
Smooth-bore.........	Cast iron.	2,600	60	..	8	4	....	45	1,070	2,280
Smooth-bore, flank defense..........	"	1,476	69	..	5.82	2	....	17	....	1,822
Mortars.										
Smooth-bore.........	Cast iron.	1,900	29.25	..	10	4	....	88	....	2,064
Smooth-bore.........	"	1,050	28.25	..	8	2.25	....	144	....	2,225
Smooth-bore, Coehorn	Bronze.	164	16.32	..	5.82	0.5	....	17	....	1,200
FIELD PIECES.										
Guns.										
Rifle.................	Wrought iron.	1,156	73.84	7	3.5	3	16.75	....	1,814	....
Rifle.................	"	880	72.65	7	3	2	10	9.5	1,418	....
Rifle (Parrott, 10-pdr.)	Cast iron.	890	77.8	3	3	1	10.5	9.75	1,232	5,000
Rifle (B. L.), Mountain, Hotchkiss...	Steel.	116.55	45.66	10	1.65	..	....	....	....	....
Cannon-revolver, Hotchkiss........	"	1212.60	66.75	6	1.457	1,851 grs.	....	7,716 grs.	1,476	....
Smooth-bore (12-pdr.)	Bronze.	1230	72.55	..	4.62	2.5	12.3	8.34	1.495	2,000
Gatling...............	Steel.	1008	68	6	1	325 grs.	8,500 gr	....	....	1,200
Gatling...............	"	865	60	6	0.5	70 "	450 "	....	1,350	1,000
Gatling...............	"	195.5	49.7	5	0.45	70 "	405 "	....	....	....
Howitzers.										
Smooth-bore.........	Bronze.	1220	82	..	6.4	3.25	Case 30.75	23.03	1,182	2,844
Smooth-bore, Mountain.............	"	220	37.21	..	4.62	0.5	Can'r 12.17	8.34	....	1,005

* Compiled by Lieut. C. S. Smith, U. S. Ordnance.

† Except for machine-guns and the Hotchkiss mountain B. L. gun, shot and shell for rifled guns are fitted with an expanding sabot, to communicate to the projectile the rotation due to the rifling. No special sabot, however, has as yet been adopted as standard. The Butler, Parrott, Arrick, and Dana all give good results.

Table showing Weight, Dimensions, etc., of U. S. Naval Ordnance.

NAME OF PIECE.	Material.	Weight.	Length.	No. of Grooves.	Calibre.	Charge of Powder.	PROJECTILE. Nature.	PROJECTILE. Weight.	PROJECTILE. Initial Velocity.
Smooth-bore Guns.		Lbs.	Feet.		Inches.	Lbs.		Lbs.	Ft. per sec.
XV. inch	Cast iron.	42,000	....	....	15	50	Shell.	352	1,100
XV. inch	"	44,000	....	....	15	100	"	352	1,600
XI. inch	"	16,000	....	....	11	20	Shot.	166	1,062
XI. inch	"	16,000	....	....	11	15	Shell.	135	1,240
IX. inch	"	9,000	....	....	9	10	"	70	1,320
32-pdr	"	4,500	....	....	6.4	6	"	26.5	....
Smooth-bore Howitzers.									
24-pdr	Bronze.	1,300	....	....	5.82	2	"	18.5	....
12-pdr	"	760	....	....	4.62	1	"	8.75	....
12-pdr	"	430	....	....	4.62	.625	"	8.75	....
12-pdr	"	300	....	....	4.62	.625	"	8.75	....
Rifled Guns.									
Parrott	Cast iron with wrought-iron reënforce.	16,300	13.6	11	8	16	"	Shell 132	....
"	"	9,700	13.0	9	6.4	8 / 10	"	80 / 100	1,140 / 1,080
"	"	5,360	10.5	....	7	6	"	48	1,320
Rifled Howitzers.									
20-pdr., heavy	Bronze.	2,000	....	....	4	2	"	20	....
20-pdr., light	"	1,340	....	....	4	2	"	20	....
12-pdr	"	880	....	....	3.4	1	"	12	....

Note.—A limited number of experimental guns have been constructed by the Ordnance Bureau of the U. S. Navy. The 11-in. smooth-bore has been converted into an 8-in. rifle. 30, 60, and 30 muzzle-loading Parrotts have been converted into breech-loaders by boring out the breech and applying the French system of fermeture. A number of small guns of bronze and steel of about 3 in. calibre have also been constructed.

Table showing Weight, Dimensions, etc., of Principal British Ordnance.

NAME OF PIECE.	Material.	Weight. Tons.	Weight. Cwt.	Weight. Lbs.	Length.	No. of Grooves.	Calibre.	Charge of Powder.	PROJECTILE. Nature.	PROJECTILE. Weight Empty.	PROJECTILE. Initial Velocity.
Royal Arsenal, Woolwich.		Tons.	Cwt.	Lbs.	In.		In.	Lbs. Oz.		Lbs. Oz.	Ft. per sec.
15.5-inch	Wr't iron.	81	..	...	324	32	15.5	37 0	Palliser.	1700 0	1,520
12-inch, No. I	"	35	..	...	191.75	9	12	.....	Common shell.	......	....
" No. II	"	25	..	...	171.50	9	12	50 0	"	460 0	1,180, 1,300
11-inch	"	25	..	...	170	9	11	50 0	"	......	1,315
10-inch	"	18	..	...	170	7	10	40 0	"	378 12	1,298, 1,364
9-inch, No. I	"	12	..	...	147	6	9	30 0	"	232 0	....
" No IV	"	12	..	...	147	6	9	30 0	"	232 0	....
8-inch. No. I	"	9	..	...	136.50	4	8	20 0	"	167 0	....
8-inch howitzer	"	..	46	...	61	4	8	....	"	......	....
7-inch, No. I	"	7	..	...	142.80	3	7	14 0	"	106 12	....
7-inch, No. V	"	4	10	...	124.50	3	7	14 0	"	106 12	1,525
64-pdr., No. I	"	..	64	...	111.50	3	6.3	8 0	"	57 9	1,017
" No. III	"	..	64	...	111.50	3	6.3	8 0	"	57 9	1,170
16-pdr	"	..	12	...	74.45	3	3.6	3 0	"	14 13	....
9-pdr., No I	"	..	8	...	68.50	3	3	1 12	"	8 8	1,330
9-pdr., No. II	"	..	6	...	58	3	3	1 8	"	8 8	1,234
9-pdr.	Bronze.	..	8	...	67	3	3	1 8	"	8 8	....
7-pdr., No. I	Steel.	..	..	150	26.5	3	3	0 6 F. G.	"	6 14	673
" No. II	Bronze.	..	..	200	36	3	3	0 8 F. G.	"	6 14	....
Sir William Armstrong & Co.											
12-inch, No. I	Wr't iron.	38	..	...	225.50	9	12	.....	"	......	....
" No. II	"	35	..	...	191.75	9	12	.....	"	575 0	1,300
" No. III	"	25	..	...	161.50	9	12	50 0	"	460 0	1,300, 1,190
11-inch	"	25	..	...	170	9	11	50 0	"	501 4	1,315, 1,247
10-inch	"	18	..	...	170.75	7	10	40 0	"	377 14	1,364, 1,298
9-inch	"	12	..	...	147	6	9	30 0	"	232 0	1,420, 1,336
8-inch	"	9	..	...	136.50	4	8	20 0	"	167 0	1,413, 1,330
7-inch, No. I	"	7	..	...	141.50	3	7	14 0	"	106 12	1,561, 1,458
" No II	"	6	10	...	126	3	7	14 0	"	106 12	1,525, 1,430
64-pdr.	"	..	64	...	111.50	3	6.3	8 0	"	57 9	1,252
40-pdr.	"	..	35	...	96	3	4.75	7 0	"	35 5	1,357, 1,336
25-pdr.	"	..	18	...	94.50	3	4	....	"	......	....
16-pdr.	"	..	12	...	72.45	3	3.6	3 0	"	14 13	1,352
9-pdr., No. I	"	..	8	...	68.50	3	3	1 12	"	8 8	1,330
7-pdr., No. I	Steel.	..	..	150	26.50	3	3	0 6	"	......	678
" No. II	"	..	..	200	38.90	3	3	0 12 F. G.	"	6 14	955
10-inch	Wr't iron.	6	..	...	77.25	7	10	.....	"	......	....
8-inch howitzer	"	..	46	...	61.125	4	8	10 5	"	167 0	....

Table showing Weigh', Dimensions, etc., of Principal British Ordnance (continued).

NAME OF PIECE.	Material.	Weight.	Length.	No. of Grooves.	Calibre.	Charge of Powder.	PROJECTILE. Nature.	Weight Empty.	Initial Velocity.
Breech-loading.		Tons. Cwt. Lbs.	In.		In.	Lbs. Oz.		Lbs. Oz.	Ft. per sec.
7-inch, No. I....	Wr't iron.	.. 82 ...	120	76	7	11 0	Common shell.	83 0 / 98 0	1,165
" No. II...	"	.. 72 ...	118	76	7	10 0	"	98 0	1,018
40-pdr., No. I....	"	.. 85 ...	121	56	4.75	5 0	"	87 14	1,180
" No. II...	"	.. 82 ...	120	56	4.75	5 0	"	87 14	....
20-pdr., No. I....	"	.. 16 ...	96	44	8.75	2 8	"	20 8	1,130
" No. II...	"	.. 15 ...	66.125	44	8.75	2 8	"	20 8	....
" No. III..	"	.. 13 ...	66.125	44	8.75	2 8	"	20 8	1,000
12-pdr.	"	.. 8 ...	72	38	3	1 8	"	10 12	1,150
9-pdr.	"	.. 6 ...	62	28	3	1 2	"	8 2¼	1,057
6-pdr.	"	.. 3 ...	60.125	32	2.5	0 12	"	......	1,046
64-pdr.	"	.. 64 ...	110	70	6.4	9 0	"	60 0	....
40-pdr.	"	.. 32 ...	98	56	4.75	5 0	"	87 14	....
Gatling, No. I....	"	.. 3 84	32	7	.45	85 Gr.R.F.G.	"	......	....
" No. II...	"	.. 7 85	62.5	7	.65	.....	"	......	....

Table showing Weight, Dimensions, etc., of German, French, and Russian Breech-loading Guns.

NAME OF PIECE.	Material.	Weight.	Length.	No. of Grooves.	Calibre.	Charge of Powder.	PROJECTILE. Nature.	Weight.	Initial Velocity.
German Guns—Krupp.		Tons.	Inches.		Inches.	Lbs.		Lbs.	Ft. per sec.
30.5 centimetre..........	Steel.	35.30	263.7	72	12.00	182	Common shell	565.5	1,510
28 c. m howitzer........	"	9.82	125.9	72	11.02	44	"	487.8	.....
Short 26 c. m...........	"	17.67	204.7	64	10.23	70.4	"	349.8	1,476
Long 24 "	"	14.38	205.9	32	9.26	52.8	"	260.7	1,391
Short 24 "	"	......	185.8	32	9.26	52.8	"	260.7	1,391
Long 21 "	"	9.84	185.8	30	8.24	37.4	"	178.8	1,440
Short 21 "	"	8.84	154.4	30	8.24	37.4	"	178.8	1,440
Long 17 "	"	5.5	167.3	48	6.77	26.4	"	100.5	1,526
Short 17 "	"	.... .	133.3	48	6.77	26.4	"	100.5	1,526
Long 15 "	"	3.08	125.4	48	5.86	17.6	"	67.0	1,526
" " " No. II.....	"	3.9	151.5	48	5.86	17.6	"	67.0	1,542
Short 15 "	"	2.9	128.7	36	5.86	17.6	"	67.0	1,526
18 c. m................	"	1.37	115.1	18	4.73	7.7	"	38.8	1,476
		Lbs.							
9 "	"	937	80.3	16	3.60	1.3	"	15.1	1,056
8 "	"	640	76.1	12	3.09	1.1	"	9.4	1,171
6 "	"	235	49.2	18	2.36	.4	"	5.0	984
French Guns.		Tons.							
32 centimetre	Cast iron and steel.	34.5	221.4	..	12.5	136.6	"	631.1	1,312
27 "	"	21.7	211.8	..	10.8	52.9	"	317.4	1,378
24 "	"	13.8	.....	..	9.4	35.2	"	220.4	1,427
19 "	"	7.9	149.0	..	7.6	17.6	"	115.1	1,486
		Cwt.							
16 "	"	93.4	.....	..	6.4	11.0	"	69.4	1,312
14 "	"	52.2	.....	..	5.4	8.8	"	41.1	1,509
Siege gun of 24 c. m.....	"	40.5	.....	..	6.0	.....	"	.....	.....
Russian Guns.		Tons.							
12-inch.................	Steel.	40.	252	36	12	.... .	"	.....	1,398
8- "	"	8.7	175	30	8	34.3	"	171.2	1,448
8- " mortar...........	"	3.2	89.9	..	8	.....	"	171.2	.....
6- "	"	3.9	140.0	..	6	.....	"	81.1	1,597
		Lbs.							
12.2-pdr. boat gun.......	......	792	67.4	..	.....	.....	"	12.2	.....

Works for Reference.—"On the Physical Conditions involved in the Construction of Artillery," Mallet, London, 1856; "Reports of Experiments on the Strength and other Properties of Metals for Cannon, and the Qualities of Cannon Powder," Rodman, Boston, 1861; "Reports of Experiments on the Strength and other Properties of Metals for Cannon," Officers of the Ordnance Dept. U. S. A., Philadelphia, 1856; "Shells and Shell-Guns," Dahlgren, Philadelphia, 1857; "A Treatise on Naval Gunnery," Douglas, London, 1860; "Boat Armament of the U. S. Navy," Dahlgren, Philadelphia, 1856; "A Course of Instruction in Ordnance and Gunnery," Benton, New York, 1867; "A Treatise on Ordnance and Naval Gunnery," Simpson, 1863; "A Treatise on Ordnance and Armor," Holley, New York, 1865; "A Text-Book of the Construction and Manufacture of the Rifled Ordnance in the British Service," Stoney and Jones, London; "The Principles and Practice of Modern Artillery," Owen, London, 1871; "The Artillerist's Manual," Gibbon, New York, 1863; "Traité d'Artillerie Théorique et Pratique," Probert, Paris, 1869; "Inspection and Proof of Cannon for the U. S. Navy," Washington, Government Printing-Office, 1864; "U. S. Navy Gunnery Notes," Washington, 1871; "U. S. Navy Laboratory Notes," Washington, 1871; "Gunpowder as an Element in the Problem of Modern Ordnance," Marvin, Washington, 1872; "Mode of Fabricating the XV-inch Guns," Bradford, Washington, 1872; "Nicaise's Belgian Field Artillery," Michaelis, New York, 1872; "A Manual of Gunnery for her Majesty's Fleet"; "Ordnance Instructions, U. S. Navy"; "Report on a

Naval Mission to Europe," Simpson, Washington, 1873; "U. S. Naval Ordnance Notes—the Reffye Gun," 1873; "Naval Ordnance and Gunnery," Cooke, New York, 1875.

See also files of *Army and Navy Journal*, *Scientific American*, *Engineering*, *Engineer*, and Journals of the Royal United Service Institution. A. A. B. (in part).

ORDNANCE—GUN-CARRIAGES. The requirements of gun-carriages are: powerful moving machinery, so contrived as to be unaffected by the concussion of firing; self-acting controlling gear, almost independent of human carelessness; the gradual absorption of shocks rather than resistance

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to them; the dispersion of concussions over large surfaces; and in vessels of war independence of distortion of or other injuries to the ship's side, smoothness and ease of motion in every direction, and safety under all conditions of the sea.

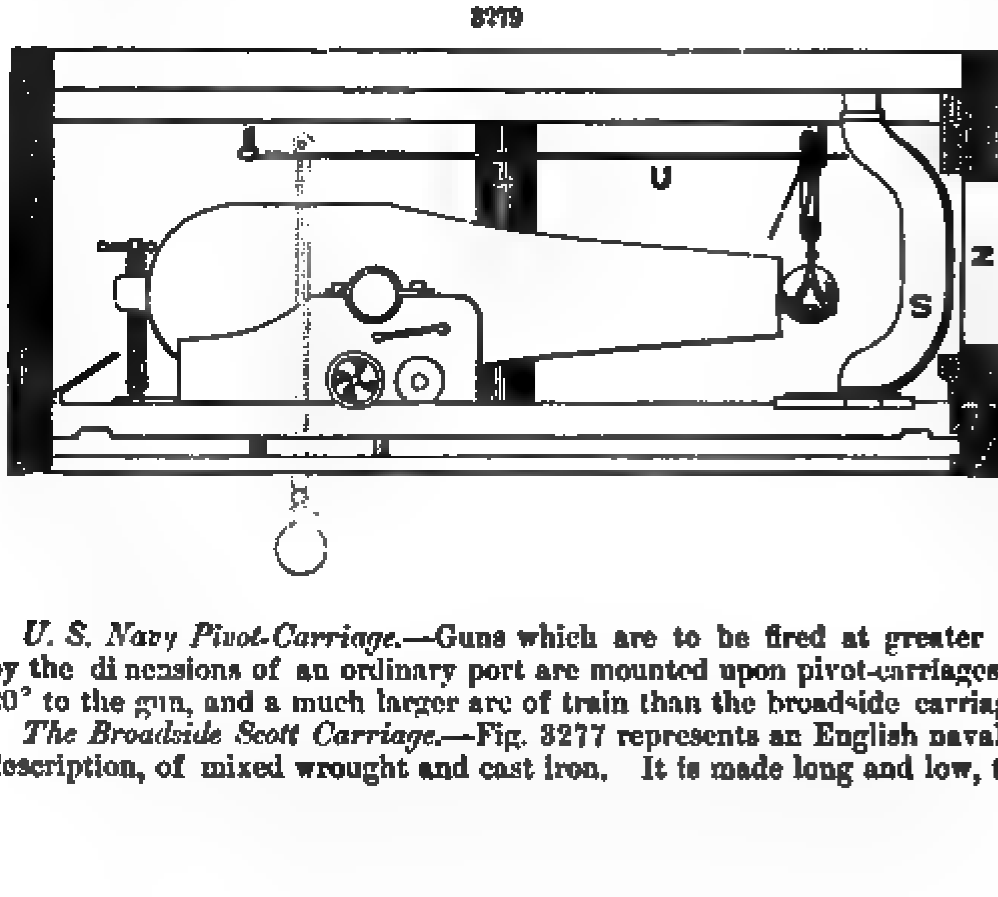
The duty of providing the most perfect means of working guns seems to be second only in importance to that of adopting the best material, form, and construction for the gun itself. Of two similar guns, that which can fire the greatest number of rounds in a given time is certainly the most effective, and rapidity of fire depends much more upon the gun-carriage and conveniences for load-

3278.

ing than upon any peculiarity attaching only to the gun. Owing to the increase in size and power of ordnance since the introduction of armor, gun-carriages have gradually become elaborate machines, and mechanical science has produced carriages and slides which enable the heaviest guns to be easily, accurately, and safely worked on the broadsides of ships. It is scarcely necessary to point out that in the construction of naval gun-carriages, owing to the limited space available, more engineering skill has been necessarily expended than in the designing of those intended for land service.

I. Naval Carriages.—The ordinary form of broadside carriage used in the U. S. Navy is the Marsilly, which has trucks only on the front axle. When the carriage is to be trained, a roller handspike is used. This is simply a lever having a metal projection at the lower end, beneath which are stout lignum-vitæ rollers. The metal projection is inserted under the rear portion of the carriage, which is then lifted by the lever and rests on the rollers, which thus serve as trucks. The carriage is thus lifted when the gun is being trained or when it is being run in or out.

3279



U. S. Navy Pivot-Carriage.—Guns which are to be fired at greater elevations than are admitted by the dimensions of an ordinary port are mounted upon pivot-carriages, which give an elevation of 20° to the gun, and a much larger arc of train than the broadside carriage.

The Broadside Scott Carriage.—Fig. 3277 represents an English naval carriage of the box-girder description, of mixed wrought and cast iron. It is made long and low, thus remedying the rearing-

back tendency of short and high carriages, and the consequent downward strain on the deck and slide.

Vavasseur's Carriage is represented in Fig. 3278. The arrangement for checking the recoil of the gun consists of a steel screw *H*, square in cross-section and of 30 in. pitch, extending nearly the entire length of the slide. The front end of the screw has fastened to it a short conic frustum, which works on a wrought-iron drum so as to form a friction-clutch.

TURRET CARRIAGES.—Fig. 3279 shows the arrangement of a U. S. monitor turret carriage. The

3280.

gun is run in and out by the hand-wheel shown at the side of the carriage, operating rack-and-pinion mechanism. *Z* is the port and *S* the swinging port-stopper. *U* is a movable rod, on which the shell-hoisting tackle traverses.

The Hydraulic Carriage and Loading Apparatus.—The hydraulic system of managing and loading guns, as applied to the turret of H. M. S. Thunderer, is represented in Fig. 3280. In this carriage all the mechanism for absorbing and regulating the force of recoil, and for moving the gun from loading to firing position or back, is replaced by a hydraulic press, which acts both to check recoil and to give motion to the gun-carriage on the slide. It is fixed on the slide in the line of recoil, with its piston-rod permanently attached to the carriage. To run the carriage in or out, it is necessary only to admit to one side or other of the piston the water delivered from the steam-pumps.

3281

When the gun recoils, the water is driven out of the press through a loaded and partly balanced valve, the resistance of which to the passage of the water arrests the recoil, and can be quickly adjusted so as to regulate the extent of recoil under different conditions. The gun is made partly muzzle-loading by hinging the slide horizontally at the rear, the front end being free to be raised or lowered upon suitable chocks from the floor of the turret at the different heights required to give the desired range of elevation to the gun in the port. The loading is effected by turning the turret so as to bring the muzzle of the gun opposite either one of two distinct sets of loading gear placed on the main deck, and locking it in this position by a catch. The gun is at the same time depressed, so that the charge may be raised to the muzzle and pushed home in the bore at an inclination from below the upper deck. The projectile is brought up to the loading place on a small trolly controlled by a friction-plate, which clamps it to the rails whenever the truck-handle is lowered. It is then run on to a hoist, which rises with it out of the main deck until arrested by stops placed so as to bring the hoist to rest when the projectile is in line with the bore of the gun. It is then pushed off the truck into the muzzle, and rammed home by a hydraulic rammer, consisting of a parallel tube in which runs a piston-rod armed with a rammer-head. A great advantage of this form of carriage is that, instead of a large gun's crew, one man in the turret and one outside may direct and control all the movements of the heaviest gun, and may load and fire it without other

help than that involved in bringing up the ammunition; and far greater rapidity of fire is obtained than is possible with manual labor. The loading positions are duplicated, so as to give a reserve in case of accident, or to enable that one to be selected which may best keep the turret-port out of the line of the enemy's fire. In the event of accident to the hydraulic loading gear, the gun may be loaded from below by hand.

3283.

The German turret carriage is represented in Fig. 3281. The chase of the gun rests on a strong swing-bed b, of forged iron, which is jointed to a bolt in the side of the turret. When the gun is raised or lowered, the trunnions slide on the swing-bed, which turns around the joint. The cheeks of the carriage project and rest on the head of the piston of the hydraulic press g. Below they are fastened to arms e, which are hinged to a lower arm d, made fast to the body of the press. The pipes i communicate from the steam-engine to the press, which is operated by a pump not shown in the engraving. For manœuvring the gun without the use of the engine, a second apparatus is provided, composed of a steel screw k, which is turned by means of a ratchet and lever l. In firing, the brake operates in the following manner: The gun recoils, taking along with it the whole hoisting arrangement. In the first instant the screw moves slightly to the rear, which causes the two friction-cones to press firmly against each other; but this motion to the rear is stopped almost immediately by the cylinder t, which is bolted to the swing-bed b. The screw pulled to the rear by the recoil of the gun causes the screw o and the frustum q to turn and communicate its motion to the drum r; but this is checked by the action of the friction-band, which must be regulated according to circumstances. A buffer, u, composed of several strong disks of India-rubber, and fastened to the rear end of the screw o, serves to stop the gun, breaking the shock gradually in case the friction of the brake has not been well regulated.

3284.

Lowering Guns.—Various systems have been devised by means of which the gun is lowered either entirely or partially below the deck, so that the men are in a protected position while engaged in loading.

The Moncrieff system is represented in one form in Fig. 3282, and is constructed on the principle of utilizing the force of the recoil to lower the whole gun, so that it can be loaded out of sight and out of exposure. That part of the carriage E which is called the elevator may be considered as a lever which has the carriage-axle at the end of the power-arm, and the centre of gravity of the counterweight C at the end of the weight-arm, there being between them a moving fulcrum. When the gun is in the firing position, the fulcrum

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on which this lever rests is almost coincident with the centre of gravity of the counterweight C; and when the gun is fired the elevators roll on the platform. Consequently the fulcrum travels away from the end of the weight-arm toward the end of the power-arm. Thus the resistance to the recoil, least at first, goes on in an increasing proportion as the gun descends, and at the end of the recoil

the parts are seized by a self-acting clutch, which when released after the gun is loaded allows the counterweight to bring the piece back to firing position.

Moncrieff's hydro-pneumatic ship carriage, Fig. 3283, is a depression carriage, in which the force of the recoil is utilized to compress a certain volume of air contained in a close vessel, and this air is afterward employed to raise the gun from under cover to the firing position.

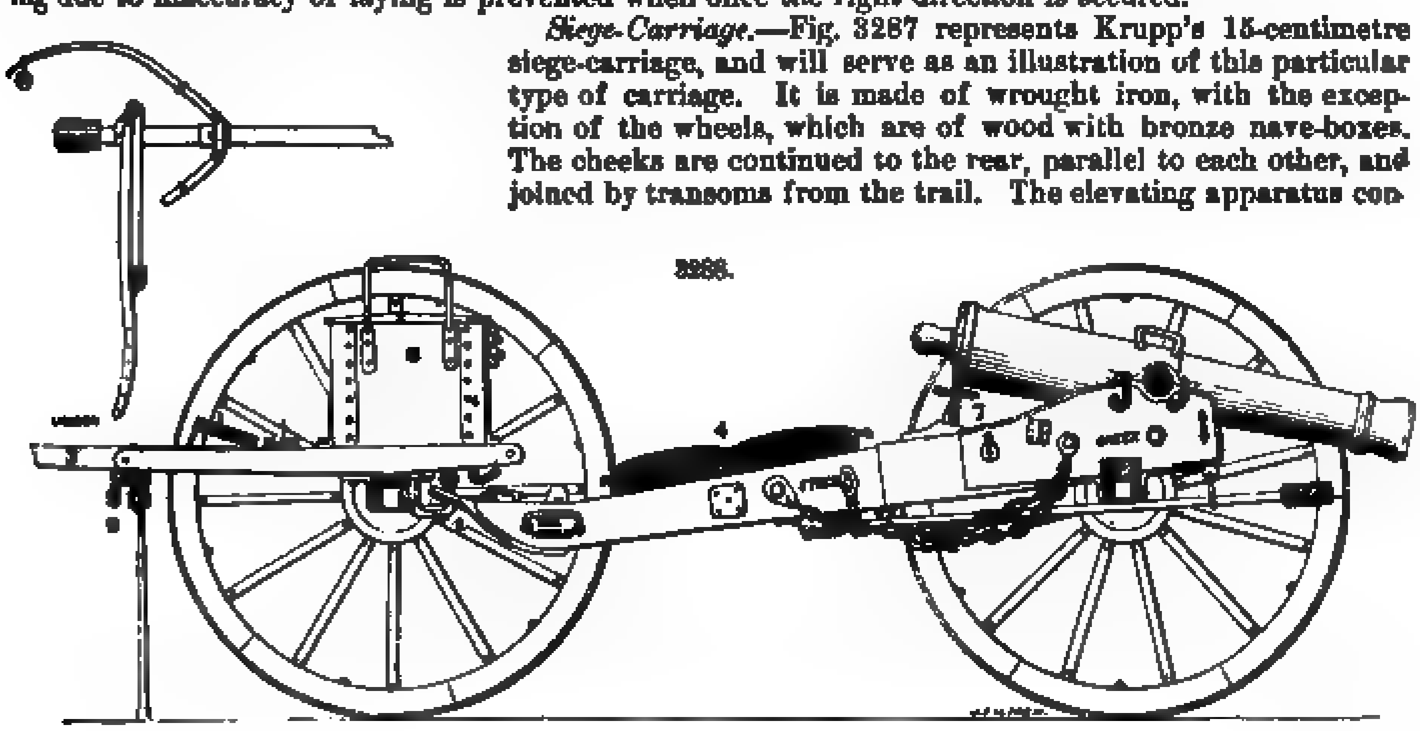
Krupp's system of working heavy guns, Fig. 3284, is essentially one for carrying a gun of considerable size on board a comparatively small vessel. The gun is trunnion-pivoted, and is capable of being lowered below the vessel's deck for the purpose of stowage, or raised so as to be brought with its platform on the same level as the deck. The gun itself has no recoil, the shock being transmitted direct to the hull of the ship. The gun rotates with the pivot to which the carriage is attached, and is thereby capable of being directed to any point of the [redacted]

II. LAND CARRIAGES.—*U. S. Barbette Carriage.*—Fig. 3285 represents the altered barbette carriage used in permanent fortifications for the 8-inch breech-loading rifle. In this, in order to check recoil, a hydraulic buffer is used, which consists of a cylinder closed at the ends by caps in which are apertures for the introduction and removal of the water.

3287.

Krupp's Protected Non-recoil Gun, Fig. 3286.—The object of this device is the complete protection of the gun, except at the muzzle. The general idea is that the gun shall pivot at the muzzle in a ball-and-socket joint, fixed into the armor of a casemate, entirely closing the port and preventing recoil. Krupp claims that when once the gun is laid true on the object, it can be fired any number of times without recoiling, jumping, or otherwise changing its position or direction in the least; so that all error in shooting due to inaccuracy of laying is prevented when once the right direction is secured.

Siege-Carriage.—Fig. 3287 represents Krupp's 15-centimetre siege-carriage, and will serve as an illustration of this particular type of carriage. It is made of wrought iron, with the exception of the wheels, which are of wood with bronze nave-boxes. The cheeks are continued to the rear, parallel to each other, and joined by transoms from the trail. The elevating apparatus consists of a single screw with a rim-wheel handle and a female screw with projecting arms terminating in trunnions, which fit in journal-boxes on the sides of the trail. The striking peculiarity of this carriage is the application of the hydraulic buffer for checking the recoil in carriages of this kind, by which means the recoil is controlled within the limits of about one yard.



3288.

Field-Carriage.—The general construction of the U. S. army field-carriage will be understood from

Fig. 3288. At 1 are the foot-boards; 2, the pintle-hook; 3, the pole; 4, the prolonge; 5, the trace-hooks; 6, the ammunition-chest; and 7, the elevating screw.

We are largely indebted for illustrations and descriptions embodied in the foregoing article to "Naval Ordnance and Gunnery,"* by Commander A. P. Cooke, U. S. N. (New York, 1875), and to a valuable report by Col. T. T. S. Laidley, U. S. Ordnance Corps, on European gunpowder, guncotton, and gun-carriages, published in "Report of Chief of Ordnance U. S. A." for 1877. To both of these works the reader is referred for detailed information, authorities, etc.

ORDNANCE—MACHINE-GUNS. Machine-guns or mitrailleuses have for their object the throwing of a continuous hail of projectiles. They may be divided into two classes: the first including those which project small-arm bullets in great numbers, and the second those which throw shells and large projectiles. The first are the mitrailleuses proper; the second, revolving cannon.

MITRAILLEUSES.—*The Gatling Gun.*—This weapon, which has proved the most successful of its class, was invented by Dr. R. J. Gatling of Indiana in 1861. It has usually five or ten barrels, each

3290.

barrel having its corresponding lock. The barrels and locks revolve together; but irrespective of this motion, the locks have a forward and backward action. The forward motion places the cartridges in the chambers of the barrels and closes the breech at the time of each discharge, while the backward motion extracts the empty cartridge-cases. The gun can be fired only when the barrels are in motion from left to right; thus the several operations of loading, firing, and extracting are carried on automatically, uniformly, and continuously. The gun is fed by feed-cases which fit in a

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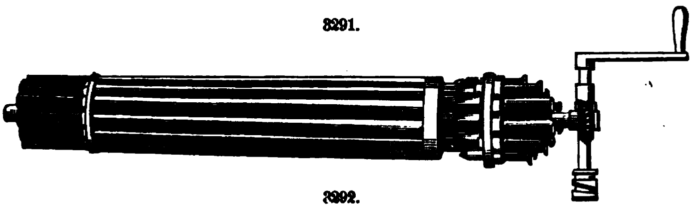
THE HOTCHKISS REVOLVING CANNON.

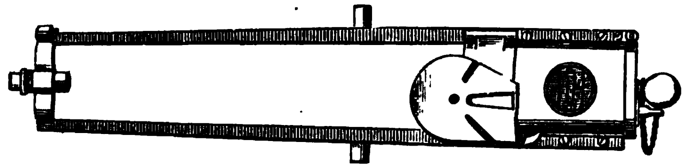
hopper communicating with the chambers. As soon as one case is emptied another takes its place, and thus continuous firing is kept up at the rate of 1,000 shots a minute. The five-barrel Gatling is mounted on a tripod, weighs only 100 lbs., and fires at the rate of 800 shots a minute.

A perspective view of the Gatling gun on its carriage is given in Fig. 3289. As regards the construction, the shape and position of the cam and grooves may be better understood by reference t' the diagram, Fig. 3290, which shows the cam-ring as it would appear if cut open and spread out flat the lines *A* and *C* being the development of the edges of the helicoidal cam surfaces, *B* that of the plane surface connecting these, and *a* and *c* the grooves for holding and drawing back the locks. The ten locks are shown in their relative positions abutting against the cam surfaces, six of them being shown in section. It will be seen that the points of the firing-pins *H* protrude beyond the front of the locks, while the other ends project from the rear, where they are fashioned into knobs, by which the firing-pins are drawn backward while passing through the groove in the rib *D*. The diagram shows that the distance of the apex *B* of the cam from the ends of the barrels is such that the locks exactly fill the space, so that each lock there forms an abutment which closes the breech of its barrel and abuts against the apex of the cam, which serves to resist the recoil of the lock when the charge

3291.



3292.



is fired. The position of the cam relatively to the cartridge-hopper is such that each lock is drawn backward to its full extent when it passes the hopper, so that the cartridges may fall into the carrier in front of the locks. The explosion of each cartridge takes place as its proper lock passes over the flat apex of the cam which resists the recoil. The rib *D* restrains the firing-pin from moving forward, while the forward movement of the body of the lock continues; the spiral mainspring is compressed until the revolution carries the firing-pin head beyond the end of the cocking-rib, when the firing-pin will spring forward and strike with its point the centre of the cartridge-head and explode the charge. The point in the revolution at which the barrels are discharged is below and at one side of the axis. Fig. 3291 represents the barrels, and Fig. 3292 the frame detached.

The Lowell Battery-Gun.—The system is composed of two distinct parts, viz.: the barrels, with their trunnions, and the frame or breech containing the mechanism. The barrels, four in number, are mounted between two supporting disks, arranged to revolve in rings. One of the peculiar features of this gun is that the firing is confined to one barrel at a time, requiring but one lock. This barrel is used until heated, disabled, or clogged, when it is rotated aside by a simple lever movement, and another is brought into place.

The Taylor Machine-Gun has in the gun proper a horizontal range of parallel rifle-barrels, five in number, securely united to each other and to a hollow breech, which contains the firing mechanism and supports upon its top the cartridge-hopper. A hand-crank operates a transverse shaft common to the firing mechanism. A full description of this gun, together with records of tests of the Lowell battery-gun above described, will be found in "Report of Chief of Ordnance U. S. A." for 1878.

Revolving Cannon.—*The Hotchkiss Revolving Cannon* is a compound machine-gun, in which it has been sought to combine the advantage of long-range shell-fire with the rapidity of action of the mitrailleuse, and therefore to produce extremely powerful effects in a minimum of time. The gun as arranged for defense against torpedo boats is represented in the full-page engraving. It is constructed to throw a shower of explosive shells with the rapidity of from 60 to 80 rounds per minute, producing as many dangerous explosions; and as each shell bursts into about 25 fragments, the gun furnishes from 1,800 to 2,000 fragments per minute, of sufficient weight to kill or disable the enemy and to damage the material, at distances equal to the range of modern field artillery. The ammunition of the gun consists of a centre-fire, spirally-rolled brass cartridge-case, forming the gas-check in the gun, and holding the powder and the projectile, and a cast-iron shell, having a central brass guiding-band to take the rifling. The bursting-charge is ignited by a percussion-fuse, requiring no preparation before use.

The revolving cannon is composed of five rifled barrels, *A A*, Fig. 3293, mounted between two disks *B* on a central axis. The barrels are rotated in front of an immovable breech-block *D*. The hollow rear portion, containing the mechanism, is closed by a door through which access may be had to the mechanism. The axis is revolved and controlled, as well as the mechanism for loading, firing, and extracting the empty cartridge-case, by means of a hand-crank *F*, Fig. 3294. The mechanism for rotating the barrels, and performing automatically the functions of loading, firing, and extracting,

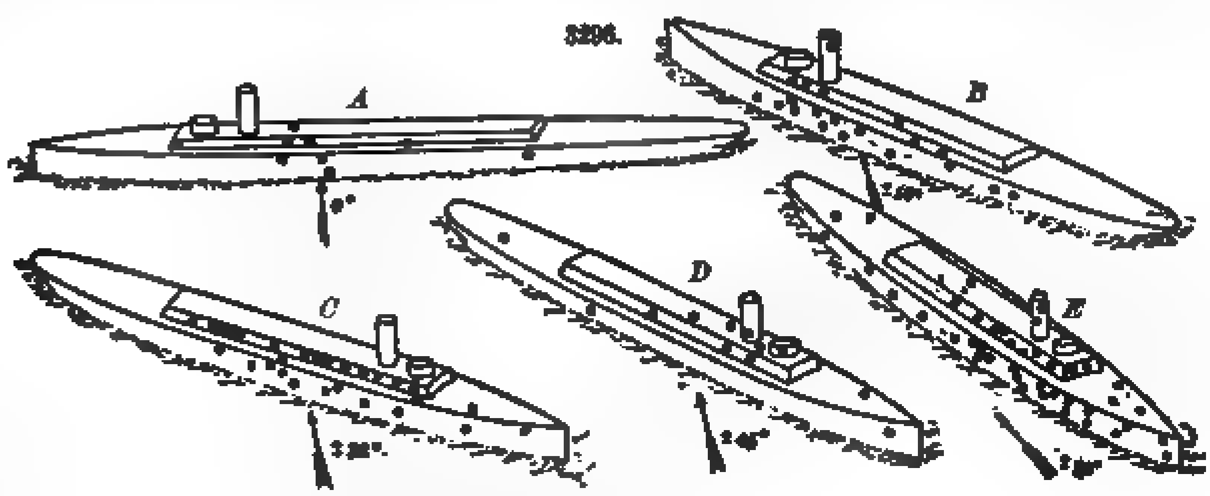
is composed of the crank-shaft G, carrying a worm H, Fig. 3295, which engages in a pin-wheel I on the rotating axis of the barrels. The worm H is curved in a peculiar manner, partly helical and partly circumferential, thus imparting an intermittent rotating motion to the group of barrels, while the worm is rotated continuously. The combination of the mechanism is so arranged that the loading, firing, and extracting take place during the time the barrels remain stationary. The worm H, Fig. 3295, carries at the same time a cam K, shaped to a logarithmic spiral. The firing-pin L bears against this cam, and is by the rotation retracted and allowed to fly forward at the proper time under the action of the spring M, and so strikes the primer and discharges the cartridge.

On the interior face of the left side of the breech, a cog-wheel N, Fig. 3293, is mounted, with two horizontal racks, O and P, running in slides. The rack O, which is attached to the loading-piston O_1, is placed above, and the other, forming the extractor, under the cog-wheel, and parallel to the axis of the barrels; so that in moving one of these racks the other is moved by the cog-wheel in the opposite direction. Part of the lower rack forms a curved slot or yoke, in which works a small crank Q, on the crank-shaft G. The rotations of the latter consequently impart an alternating and opposite movement to the racks, so that while the one is going forward the other moves back, and reciprocally; thus a fired cartridge-case is extracted, while a loaded cartridge is introduced into the barrel above. The introduction-trough, or receiver, in which the loading-piston works, is closed by a hinged gate R, Fig. 3294, which goes down by the weight of the cartridges, the first of which enters the trough, and then the loading-piston in moving forward raises the gate, and isolates the other cartridges from the one in the act of being loaded into the barrel.

3295.

The operation of the mechanism may be described as follows, supposing the crank to be in continual motion: A cartridge is placed in the introduction-trough; the loading-piston O_1 pushes it into the barrel; then the barrels begin to revolve, and the cartridge is carried on until it arrives before the firing-pin L, which penetrates the solid part of the breech, and which has in the mean time been retracted by the action of the cam K; then, as soon as the cartridge has arrived in this position, the barrels cease to revolve, and the primer of the cartridge is struck by the firing-pin and discharged. Then the revolution of the barrels begins again, and the fired cartridge-shell is carried on until it comes to the extractor. This in the mean time has arrived up to the barrels, and the cartridge head rolls into it. As soon as the head is laid hold of by the extractor, the barrels again cease to revolve, and during this period the cartridge-shell is withdrawn and dropped to the ground. As during every stoppage of the barrels the gun is supplied with a new cartridge, and the firing and extraction are performed during this time, a continuous but slow fire is kept up. By supplying the gun in this manner with single cartridges, about 30 rounds per minute may be fired.

3296.



The following data show the capacity, etc. of the largest size of this gun: diameter of barrel, 2.06 in.; weight, 3,300 lbs.; weight of projectile, 56.1 oz.; bursting-charge of same, 1.95 oz.; charge of powder, 3.93 oz.; initial velocity, 1,456 ft. per second; extreme range, 7,466 yards.

A remarkable series of experiments was conducted with the Hotchkiss revolving cannon by the Dutch Government at Helder in September, 1878, the object being to test the gun as a means of defense against torpedo attack. For this purpose a target corresponding in shape to a Thorneycroft torpedo-boat was built, its dimensions being—length, 75 ft. 5¼ in.; width, 6 ft. 10¾ in.; height above water-line, mean, 33.4 in. The experiments may be summarized as follows, the effects of the hits being noted in Fig. 3296:

Experiment 1, *A*.—Vessel carrying gun anchored at 1,968 ft. from target, the latter presenting a broadside. No. of rounds fired, 24; time, 80 seconds. Percentage of projectiles which hit, 50.

Experiment 2, *B*.—Vessel anchored as before. Target placed at angle of 50° with line of fire. No. of rounds, 28; time, 90 seconds; proportion of hits to rounds, 71¼ per cent.

Experiment 3, *C*.—Vessel moving at 10 knots per hour, starting from point 2,624 ft. distant from target, which was laid at an angle of 30° with the line of fire. No. of rounds, 46; time, 2¼ minutes; proportion of hits to rounds fired, 51 per cent.

Experiment 4, *D*.—Same conditions. Run of 800 ft., beginning at 500 yards from target. No. of rounds, 20; time, 1¼ minute; proportion of hits to rounds fired, 60 per cent.

Experiment 5, *E*.—Vessel moving end on to target at 10 knots, starting from point 2,444 ft. distant. No. of rounds, 53; time, 3¼ minutes; proportion of hits to rounds fired, 77.4 per cent.

These trials were conducted by the commandant of naval artillery Kruys, who in his official report says that against these guns a daylight attack by torpedo-boats could not have the smallest chance of success, while the danger would be so great and useless that such an attempt would scarcely be made. Four such guns are absolutely necessary to protect a ship on all sides, and to secure the impossibility of any boat approaching without entering the zone of one or other of the guns.

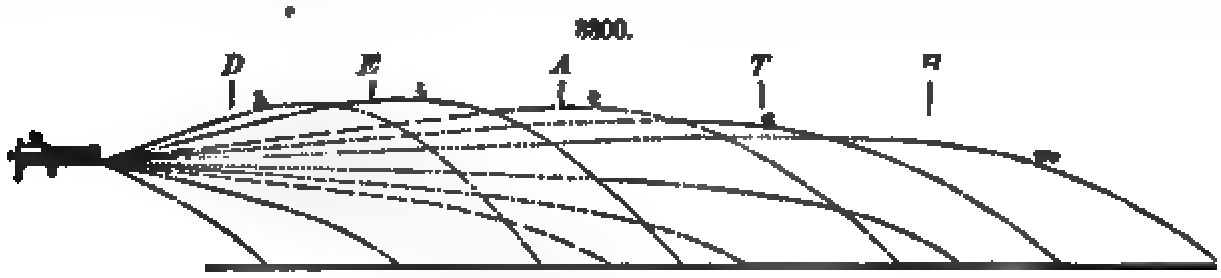
3299.

3297.

3298.

One of the most remarkable capabilities of the revolving cannon is the mode in which it defends ditches or trenches. Actual experiments have determined that the angle of the cone of dispersion of the bullets of case or canister shot, fired from rifled guns, is determined by the pitch of the rifling. It has also been determined in like manner that all of the balls fly near the periphery or outer part of this cone. These facts indicate the inefficiency of ordinary guns for flanking and similar purposes. Figs. 3297 and 3298 show, in sectional elevation and plan, the path of travel of the cone of dispersion of the bullets of case or canister shot fired from an ordinary cannon, from which it will be seen that there is a large space not at all covered by the path of travel of the balls, in which an enemy might pass with impunity. In order to cover the entire space between the longest and shortest range of such a cannon, it must be adjusted at different degrees of elevation. If it were possible to fire such an ordinary cannon with great rapidity, and to change its elevation with like expedition, the result might be accomplished; but in that case, since the cone of dispersion of the balls would always remain the same, no matter at what elevation it was fired, the space covered at short range would be comparatively ineffectually protected. With a machine-gun having two or more barrels automatically loaded and fired, and provided with means for changing the elevation for each barrel discharged, this could not only be accomplished, but would become quite effective in consequence of the rapidity of the firing. In Fig. 3299 is illustrated one means for changing the elevation of a machine-gun just before each barrel is fired. It consists in providing the disk *A*, which supports the rear ends of and turns with the barrels, with a cam-surface *B*, which rests upon

3300.

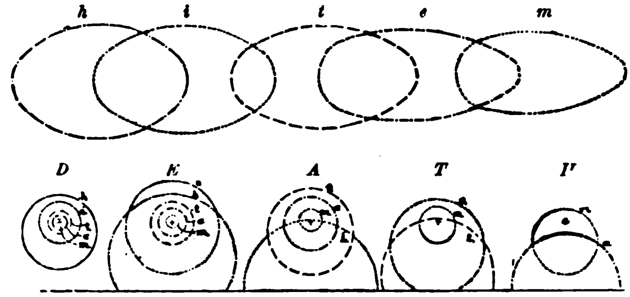


a fixed bearing or a friction-roll, as *C*, supported by the carriage of the gun. This cam-surface, being properly shaped to support each barrel at a different elevation, will, as the barrels are revolved by the actuating crank-shaft, automatically raise them, as is apparent from an inspection of the drawing.

To render a gun most effective in protecting the ditch of a fortification, the approaches thereto

and generally for flanking purposes, constitutes one object of this invention. In carrying out this feature of the invention the inventor takes advantage of the fact, as demonstrated by experiments, that the bullets in their course of flight assume the form of a hollow cone, the angle of whose periphery depends upon the pitch of the rifling of the barrel, and constructs a gun having two or more barrels, so that the pitch of the rifling of each barrel varies in degree. With a gun thus constructed, since the cone of dispersion of the bullets from each barrel is of different extent at different distances from the gun, and the trajectory of each cone of bullets will also vary, it becomes evident that if the pitch of the rifling of the several barrels is properly determined any extent of space within the range of the gun may be effectively covered. This will be readily apparent from Figs. 3300 and 3301, in which are illustrated, in longitudinal and transverse sectional outline, the courses of flight and surface deposit of the balls discharged from a cannon having five barrels, which barrels are each provided with rifling of a different pitch. Thus the course of the hollow cone of bullets discharged from the first barrel, supposed to be provided with rifling of a quick twist, will approximate to that marked *h*; the cone formed by the bullets discharged from the second barrel, provided with rifling of less rapid twist, will approximate to that marked *i*; the cones formed by the bullets fired from the third, fourth, and fifth barrels, each provided with rifling the pitch of whose twist diminishes in a regular degree, will approximate to the outlines *t*, *e*, *m*, respectively. If, now, the transverse sections taken at the various points be indicated by the lines *D E A T H*, it will be found that, throughout the whole extent of ground covered by the longest to the shortest range, there is no vertical or horizontal space that is not adequately covered by some one or more of the cones of balls.

3301.



ORDNANCE, MANUFACTURE OF. Materials.—The fitness of metals for cannon depends chiefly on the amount of their elongation within the elastic limit, and the amount of pressure required to produce this elongation; that is to say, upon their elasticity. It also depends, if the least possible weight is to be combined with the greatest possible preventive against explosive bursting, upon the amount of elongation and the corresponding pressure beyond the elastic limit; that is to say, upon the ductility of the metal.

Cast iron has the least ultimate tenacity, elasticity, and ductility; but it is harder than bronze or wrought iron, and more uniform and trustworthy than wrought iron, because it is homogeneous. The unequal cooling of solid castings leaves them under initial rupturing strains; but hollow casting and cooling from within remedies this defect. The best American cast iron has a strength of about 37,000 lbs. per square inch, and yields usually less than 1 per cent.

Wrought iron has the advantage of a considerable amount of elasticity, a high degree of ductility, and a greater ultimate tenacity than cast iron; but as large masses must be welded up from small pieces, this tenacity cannot be depended upon. Another serious defect of wrought iron is its softness and consequent yielding under pressure and friction. The average tensile strength of the best qualities of wrought iron is about 60,000 lbs. per square inch, or about double that of the best qualities of cast gun-iron.

Steel.—The obvious defect of high steel for cannon is its brittleness; but if so large a mass is used that its elastic limit will never be exceeded, or if it is jacketed with a less extensible metal, this defect is remedied or modified. Low steel is a much more suitable metal for cannon-making, as it possesses elasticity, tenacity, and hardness. Its tenacity averages about 90,000 lbs. per square inch. Whitworth's fluid-compressed steel, made by Sir Joseph Whitworth & Co. of Manchester, England, has proved of exceeding value for cannon-making. This metal is subjected, while in a liquid state, to a heavy pressure for the purpose of expelling air-bubbles, and is afterward reheated and hammered to secure uniformity and regularity of structure. A record of extended tests of this material will be found in the "Report of the Chief of Ordnance U. S. A." for 1878. The following mean mechanical properties were adduced: Density, 7.855; tenacity of piece, area 0.65 sq. in., 110,000 lbs.; elastic limit under pulling stress, piece 10 in. long by .34 sq. in. area, 38,500 lbs.; same under thrusting stress, 28,000 lbs.; hardness, 16.230; hardness of copper, 5.000.

Bronze has a mean ultimate cohesion of about 33,000 lbs. per square inch. It has greater ultimate tenacity than cast iron, but it has little more elasticity and less homogeneity. It has a high degree of ductility, but it is the softest of cannon-metals, and is injuriously affected by the heat of high charges. (See "Admiralty Experiments on Gun-Metals," under Alloys.) Additional strength has been imparted to bronze guns by condensation of the metals, as described under Dean's gun in Ordnance, Construction of. This gun is cast solid, bored out, and the bore is then enlarged by forcing mandrels of gradually increasing size through it. The effect is shown by the following figures: Sample of bronze not condensed—density 8.3512, tenacity 38,810 lbs.; condensed—density 8.7065, tenacity 51,571 lbs. The hardness is increased nearly fivefold.

The following table, from "Reports of Experiments on Metals for Cannon, U. S. Ordnance Department, 1856," exhibits the variations which occur in various qualities of metals:

Table showing Maximum and Minimum Strength of Cannon-Metals.

Metals.		Density.	Tenacity.	Transverse Strength.	Compressive Strength.	Hardness.
Cast iron	Least	6.900	9,000	5,000	84,529	4.57
	Greatest	7.400	45,970	11,500	174,120	28.51
Wrought iron	Least	7.704	38,027	6,500	40,000	10.45
	Greatest	7.858	74,592	......	127,720	12.41
Bronze	Least	7.978	17,698	......	......	4.57
	Greatest	8.953	56,786	......	......	5.94
Cast steel	Least	7.729	....	......	198,944	....
	Greatest	7.862	128,000	28,000	391,985	...

Manufacture of Cast Guns.—Commander R. F. Bradford, U. S. N., in "Navy Ordnance Papers," No. 3, gives the following details of the method of casting a 15-inch gun at the Fort Pitt Foundry,

Pittsburgh, Pa. Two reverberatory air-furnaces are used for melting the iron of which the gun is made, the draught being produced by high chimneys instead of a blast. A circular flask, Fig. 3302, is used, consisting of five upright sections, secured together by clamps fitting over flanges *A A A*,

at either end of the sections. Its thickness is 1 in., and it is pierced with holes. The entire length of the flask is 20 ft., and it is made in five sections, viz.: that for the breech, *B B*; the cylinder, *C*; the trunnion-section, *D*; and two upper sections, *E* and *F*, the latter being 3 ft. longer than the required length of gun to admit of a sinking-head. The pattern is in five sections, slightly tapered. The core-barrel consists of a water-tight iron tube about 15 ft. long and three-quarters of an inch thick, its exterior diameter at the head being 12 in. and tapering a quarter of an inch to facilitate withdrawing. It is fluted to allow of escape of gas, and is covered with hemp stuff, a moulding composition, and coke-wash. The pit is circular in form, and has brick walls and a sheet-iron tank at the bottom. After the flask is placed, the core is adjusted by the spider *S*, which is of cast iron, having legs which are provided with adjustable screws, which in turn rest on the upper flange of the mould. When adjusted, it is secured by clamps *H*. The molten metal is led in troughs to the side gates *R*, and enters the mould by the branch gates *b b b*. As soon after the cast as possible a fire is built in the pit about the bottom of the flask, and kept up for four or five days. Water for cooling is conducted to the bottom of the core-barrel by the tube *T*, whence it ascends through the annular space between the tubes, and is discharged from the core-barrel at *V*. After an interval of 18 hours after casting, the core-barrel is removed and a continuous stream of air is forced into the bore. The cooling occupies about eight or nine days for a 15-inch naval gun, which in the rough state, including sinking-head, etc., weighs 66,000 lbs.

Gun-boring.—The casting is first placed in a heading-lathe, Fig. 3303, where it is prepared for the boring-lathe. The cascable-bearing, base of breech, and a section of the chase are all turned down to finished dimensions while in this lathe, as the chase and rounded part of the cascable-knob form the bearings for the boring-lathe. *A* represents the muzzle-ring with adjustable screws; *B*, the bearing in which the muzzle-ring revolves; *C*, the chuck or mortise into which the square knob of the cascable is inserted and secured; and *D*, the tools or cutters with rests. The first cut is usually an inch deep, commencing at the muzzle where the sinking-head is to be cut off, and extending to the trunnions. After the metal is reduced to finishing diameter, the sinking-head is broken or wedged off, and the gun is taken to the boring-lathe, shown in Fig. 3304. This consists of a rack *R*, journals *A*, and boring-rod *B*, the supports of which rest upon the rack, and are of such a height that the axes of the journals and boring-rod shall be in the same horizontal plane. In boring a 15-inch gun, the first cutter is 14 in. in diameter, and is secured on the end of the rod *B*. When the bottom of the cylindrical portion of the bore is reached, the chamber is roughed out, and a reamer, first for the cylinder and then for the chamber, is introduced. During the boring process (except while reaming) the turning of the exterior progresses. The gun is next placed in the trunnion-lathe, where a hollow shaft is made to revolve about the trunnion, the gun being stationary; and as the turning continues, the shaft moves on its rack toward the gun. The metal in excess between the trunnions is removed by a planing-machine, which is placed on the side opposite the trunnion-machine, and is so arranged that the movable post in which the cutter is secured, *A*, traverses forward and back over the desired portion of the gun. The gun is turned the width of the cut after each passage of the planer. The desired curve of metal is obtained by introducing a guide-plate *C*, of proper form, in rear of the cutter-rest. The surplus metal about the rim-bases, lock, and sight-masses is reduced by chipping and finished by hand. The hole is then cut for the elevating screw, and the vent is drilled. This form of smooth-bore cast gun has been extensively used in the U. S. service, this mode of casting upon a core and gradually cooling from the interior having been first practised by Gen. Rodman, and greatly increasing the strength of the gun. The 15-inch Rodman gun, cast and finished upon this method, weighs 42,000 lbs.

Manufacture of Built-up Guns.—The terms built-up and hooped are applied to those cannon in which the principal parts are formed separately, and then united in a peculiar manner. They are not necessarily composed of more than one kind of metal, some of the most important being made of steel alone; and they may be made by welding or by screwing the parts together, or by shrinking or forcing one part over another. The object is to correct the defects of one material by uniting with

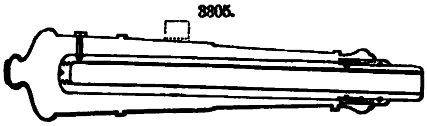
it opposite qualities of the same or other materials. The defects which follow the working of large masses of iron or steel, such as crystalline structure, false welds, cracks, etc., are avoided by first forming the parts of small masses of good quality, and then uniting them separately. The principal methods of manufacture involve either the shrinking on or the forcing on of the hoops. The difficulties incident to the first process are the necessity of accurately boring the hoops and the unequal shrinkage liable to occur in the separate pieces of metal. Hoops are forced on by hydrostatic pressure with much more successful results. Various methods of constructing built-up guns will be found detailed under the descriptions of the guns in ORDNANCE, CONSTRUCTION OF.

RIFLING HEAVY ORDNANCE.—The machine used for rifling guns for the British service is horizontal, and the gun to be rifled is placed in front of and in line with the rifling-bar, to which a stout head carrying the cutter is fixed. A single groove is cut at a time, each groove being first made roughly and afterward finely finished. The distance apart of the grooves (or width of lands) is regulated by a notched disk fixed to the breech of the gun, the notches being equidistant on the periphery of the disk, and there are as many notches as there are grooves. When one groove is cut, the gun is turned to the next notch, and held by a pawl. The gun remains stationary, and the cutter works up and down the bore; but in order to give the required twist to the rifling, it is made to turn slightly as it moves longitudinally. The cutter is fixed in a head of gun-metal made exactly to fit the bore. It is fastened to a hollow iron bar, which is fixed to a saddle made to move backward and forward, but so arranged as not to prevent the motion of the rifling-bar upon its axis. At the other end, at right angles to the bar, is fixed a rack and pinion, sliding on the saddle. The outer end of this rack is fitted with two friction-rollers, which move along a straight copying-bar attached to one side of the machine, and which may be adjusted to any angle with it, thus regulating the twist; or a curved bar may be used if the gaining-twist is desired. The cutter is of steel, and attached to a bar of its own, passing through the rifling-bar, the outer end having a system of levers and counterweights, which push the cutter out while the head is emerging, and withdraw it while the head is entering. The movement of the cutter-shaft is regulated by means of another copying apparatus on the other side of the machine. This arrangement consists of two horizontal bars, one higher than the other. A pinion to which is attached a loaded lever works the slide. While the rifling-head is passing down the bore, this lever moves along the upper bar; but by reversing the machine, the weight feeds on the lower bar, drawing back the slide and spindle, and forces the tool out. The depth of groove at any point is regulated by varying the upper surface of the lower bars.

CONVERTED GUNS.—A large amount of experimenting has been conducted by various nations with a view to convert smooth-bore cannon into rifled guns, by lining-tubes and other devices.

Parsons's method, one of the first proposed to the English Government, consists in introducing into the bore of the cast-iron gun a rifled tube of steel. Palliser's method, which was adopted by the English Ordnance Committee in preference to Parsons's, is substantially the same thing. It is illustrated in Fig. 3305. The tube is of coiled wrought iron, the breech end being a double tube, and the outer envelope being shrunk on the inner lining. The double tube is of the same thickness as the single tube at the muzzle. The gun to be converted is bored up to an increased calibre of about one-third its former diameter, forming a true cylinder or slightly tapering conical form. A slight amount of play is permitted between the tube and casing, which is taken out by a setting-up charge expanding the tube into the casing. The tube at the breech end is closed by a capped wrought-iron plug screwed into it. The tube at the muzzle end is secured by a screw-collar, and prevented from any motion about its axis by a screw tapped through the casing and into the tube. The old vent is closed, and a new one with copper bush passed through the breech-plug. A spiral channel around the outside of the tube, communicating with a small hole in the breech of the cast-iron casing, allows the gas to escape if the tube should split, and gives warning of such defect. This gun, though not considered equal to the built-up gun, has stood severe experimental tests and given satisfactory results, and many English ships and forts have been armed with it.

3305.



Various methods of converting the old cast guns by simply rifling them without the introduction of a tube have been suggested, the difference being simply in the shape and number of grooves, and degree of twist.

A series of experiments has been conducted by the Ordnance Department, U. S. A., Lieut.-Col. Silas Crispin in charge, on various systems of converting smooth-bore guns into rifles by lining them with tubes of wrought iron and steel. A full report of these experiments will be found in "Report of Chief of Ordnance U. S. A." for 1878. The systems tested were as follows:

1. A cast-iron body or casing of the Rodman model was lined with a coiled wrought-iron tube inserted from the muzzle, forming a 12¼-inch rifle-gun.

2. A 13-inch Rodman smooth-bore gun was bored up to a diameter of 17 in., and lined with a coiled wrought-iron tube inserted from the muzzle, so as to form a 10-inch muzzle-loading rifle-gun.

3. Considerable difficulty has been found in securing perfect weldings in coiled wrought-iron tubes, defective welds often resulting in grave accidents in service. Experiments were therefore made upon a mode of construction in which a jacket is shrunk on the tube, and extends continuously with a uniform thickness from a point a short distance in front of the trunnions to the breech-cap of the inner tube, and thence, with an increased thickness, clear through the breech to its face. This arrangement was modified by substituting a jacket which is prolonged to the rear and adapted for the reception of a round-wedge fermeture.

In Fig. 3306, *C* is the cast-iron casing, which consists of a 10-inch Rodman smooth-bore gun, cut off at the breech to a length of 123.25 in., and bored up to the requisite diameters to receive the

tube A with its jacket B, which is inserted at the breech. The tube is made of coiled wrought iron, and is of equal length with the casing. It is reënforced at the breech end for a distance of 40 in. by a steel jacket, which is united with it by shrinkage. The breech of the jacket is prolonged 24 in. to the rear of the casing and tube, and is fitted for the reception of the mechanism of the breech fermeture. The united jacket and tube are inserted in the casing with a shrinkage of 0.006 in. over the jacket, while the tube in front has a play of about the same amount. They are held in position by a thread $a\,a$ and the muzzle-collar b, also the shoulder $c\,c$. The breech of the casing is reënforced by the steel breech-band D, which is put on under a shrinkage of 0.03 in. and secured by the pin h. The breech mechanism works in a slot cut in the prolongation of the steel jacket to the rear of the casing and tube, and is, in all its essential features, the same as that used in the Krupp breech-loading guns of heavy calibre.

3306.

The results of the experiments led to the conclusion that the system described of breech insertion is superior in strength to muzzle insertion; also that the facilities it introduces for the employment of shoulders, to prevent any accidental blowing out of the tube likely to arise from the common defect of imperfect welding, gives it an important advantage over muzzle insertion. It was recommended that in future conversions of smooth-bore guns the breech-insertion plan be employed.

ORE-CONCENTRATORS. See CONCENTRATING MACHINERY.

ORE-CRUSHER. See BREAKERS OR CRUSHERS.

ORE-MILLS. See MILLS, GOLD AND SILVER.

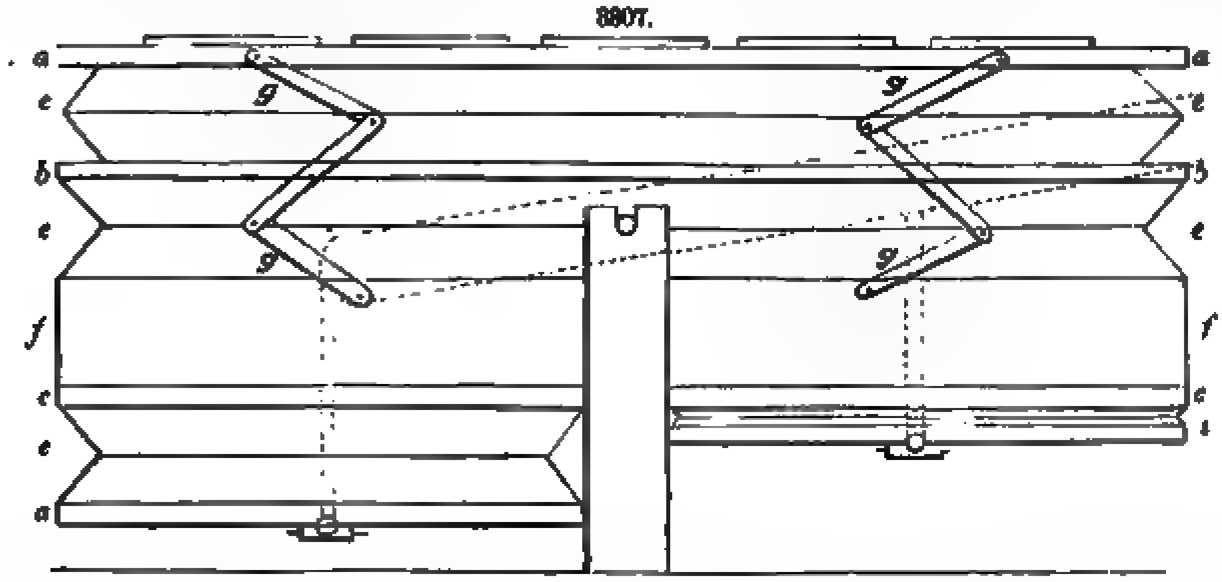
ORE-ROASTERS. See FURNACES, METALLURGICAL.

ORE-STAMPS. See STAMPS, ORE.

ORGANS, PIPE. The pipe organ may be described as a combination of different musical instruments brought under the control of one performer, through the mechanism of keys which are played by the hands and feet. In this manner imitations can be produced of the trumpet, flute, violin, clarionet, etc.; and in addition are produced the original organ tones, such as the diapason, dulciana, and the like, which have no counterpart in an orchestra. The various sounds are produced through the medium of compressed air, which is admitted to the pipes by the opening of valves controlled by the keys on which the organist plays. The keys controlled by the hands are called manual keys, and are similar to those of a piano. They vary from one to four or five sets or banks placed one above the other. The keys played by the feet are called pedals, and are conveniently disposed on the floor.

Methods of Blowing.—The usual form of bellows which compresses and stores the air is represented in Fig. 3307. Rotary motion is obtained by using three feeders, moved by means of a shaft, cranks, and balance-wheel, the feeder-cranks being set at equal angles. The size of the bellows

3307.



should be ample to sustain the supply of wind with every stop drawn (except the tremolo) in the following chords: Treble. E, G, C, E; bass, C, E, G, C; pedal, C, G; including also the couplers. The ordinary way of operating the bellows is by hand, and might be likened to pumping. In localities where there is water-pressure, this labor is performed by a water-pressure engine. (See ENGINES, WATER-PRESSURE.) The supply of wind to the bellows is made automatic by an attachment at the top of the reservoir of the bellows, so that when the reservoir rises it gradually closes the valve that supplies water to the motor. When the reservoir is full the water is shut off and the engine stops; but as the reservoir falls it gradually opens the valve and allows the engine to start again. This is the simplest mechanical way of blowing the organ.

Fig. 3308 represents the Schriver water-engine. A is the water-cylinder. b is the piston-rod, and c is the valve-rod, which works a piston slide-valve C, and directs the water to one or the other end of the cylinder, as required, allowing its free escape always from the opposite end. The water is inducted to the cylinder through the pipe D, and is allowed to flow away through the pipe E. M is a valve mounted in a sufficiently enlarged portion of the waterway forming the pipe D. It is con-

trolled by an arm M' on its shaft m. When this valve is turned in the proper position, it is of no effect. This is the position which it maintains during the main portion of each stroke; but immediately before the end of each stroke it is turned so as to gradually moderate and nearly stop the flow of the water. When the motion has been thus moderated, the valve C changes its position, and the water is directed to the opposite end of the cylinder. So soon as this change is effected, the valve M is again turned in a wide-open position, and remains so until near the end of the next stroke, when the operation of gradually closing and arresting the flow of the water is repeated. When the water-engine is employed to act against a reliable resistance, as in pumping air, the valve M may be turned by acting on its arm M' by stops adjusted on a reciprocating rod carried by the piston. P represents the rod, which is rigidly connected to the piston-rod. It carries two stops, P^1, P^2, which may be adjusted by means of pinching-screws. When the engine has nearly completed its stroke in the downward direction, the stop P^1 strikes the arm M' and turns the valve M, to check the flow. When it has nearly completed its motion in the upward direction, the stop P^2 strikes the arm M' and turns it in the other direction, to stop the flow. After being turned in either direction, the valve M is reliably turned back to its open position by the action of a T-shaped piece of metal R, which is pressed up by a spring T, and, by acting under the lever M', exerts a constant force, which returns

3308.

the valve to its wide-open position the moment it is released from the influence of the respective stops P^1, P^2.

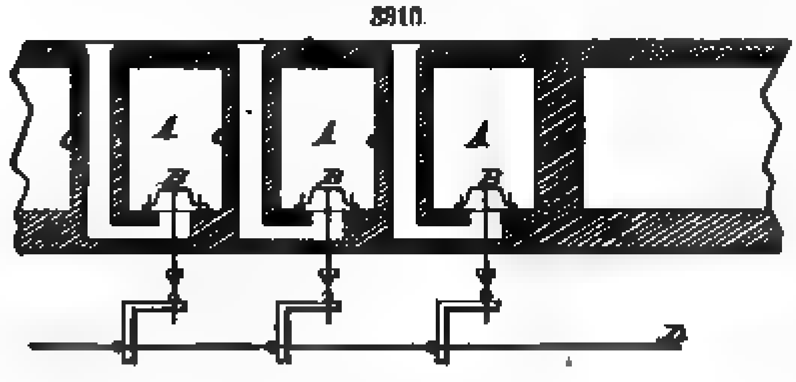
Where water cannot be obtained, a hot-air engine may be used, the "Rider compression engine"

having been used for the purpose. (See ENGINES, AIR.) In this case the speed of the engine cannot be readily controlled; therefore the reservoir or bellows when full is made to open valves into the feeders themselves, allowing surplus air to escape back into the feeders, the engine always running at the same speed. The supply of wind in this case remains steady. Another means of blowing is by the use of the steam-engine, in which case the supply of wind can be regulated where a double engine is used by simply cutting off the supply of steam. The consumption of fuel required for an air-engine of the type named is about a scuttleful for a service. The Music Hall organ in Boston, and the open-air organ at Newport belonging to the late Thomas Winans, are blown by steam-engines.

Wind-Chests.—The air, after being compressed in the bellows, flows through channels to the wind-chests, whence it is distributed at the will of the organist among the various stops. There are several constructions of wind-chests. Fig. 3309, from Clarke's "Outline of the Structure of the Pipe Organ," represents the usual form. The sound-board is divided by partitions A into as many channels B as there are keys at the manuals. At C is the table or veneer; above this are the slides D, fitted with bolsters, and the top board E. At F are the valve-pallets, each valve being kept in place by a spring. M is the pipe-rack.

In this construction of wind-chest, one large valve supplies many pipes, and for the ordinary construction of smaller organs it is found to answer all purposes. But in the construction of very large instruments other means have been required of supplying the air to the pipes. Fig. 3310 represents the German wind-chest, invented by Herr Walcker, builder of the Boston Music Hall organ. In this each pipe has a valve of its own. The diagram shows a cross-section. The spaces A are chambers running longitudinally, one for each set of pipes or stop. Drawing on a stop simply opens a large valve admitting the compressed air to one of these chambers. B represents the small valves which admit the wind to the separate pipes. By depressing a key the tracker D is drawn forward, thereby opening the valves B. If there is compressed air in any of the chambers A A, the pipes over those chambers will speak. The lower section E is glued fast to the partitions C; therefore no access can be had to the interior of the chambers except from above, by removing the upper board F, which necessitates the removal of all the pipes thereon.

3310.



It can be seen at a glance that the mechanism necessary to control so many little valves must be necessarily complicated and liable to derangement from atmospheric changes, etc.; and that it is probable that the touch may be found to be quite heavy owing to the organist having so much mechanism to put in operation. But there are many advantages to be gained in the musical effect of the organ when each pipe has its own valve. Many researches have been made to construct a wind-chest thus arranged. A device of this kind, by Mr. Hilborne L. Roosevelt of New York, is represented in Fig. 3311. This wind-chest resembles Walcker's in having the air-chambers A running longitudinally, but the valves are differently placed, as shown. The object in this construction is to substitute compressed air for the mechanism used by Walcker, thereby gaining lightness of touch, accessibility to the valves from below by simply removing the bottom boards B, non-liability to derangement from atmospheric changes, no parts to be regulated, and no buttons to slip; the positive motion of the bellows thus insuring a full supply of wind to the pipes. The operation of this sound board may be briefly described as follows: Depressing the key pulls the tracker C, thereby opening the valves D, allowing the compressed air to escape from the groove B, the effect of which is to exhaust the small bellows E, thereby opening the valves F. These small bellows are placed directly opposite the valves, and have about twice the area of surface that the valves have, and are therefore strong enough to overcome the pressure on the valve and spring G.

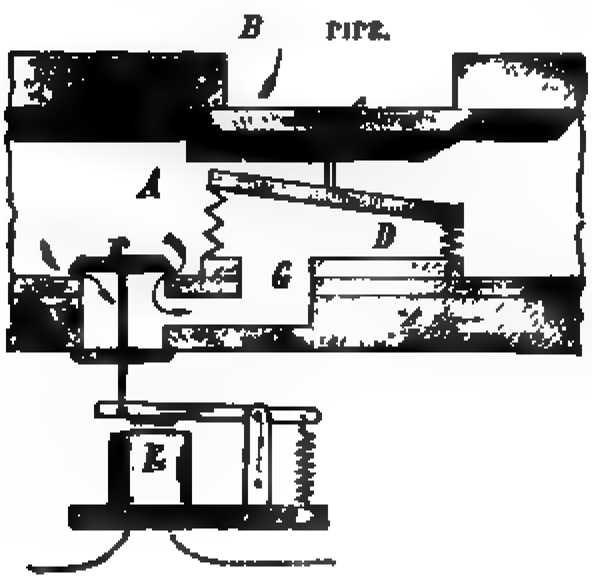
3311

Key Action.—There are various ways of constructing the keys to the valves, which it is not necessary here to describe. In some organs the pressure needed to sound one key with full organ and all the couplers drawn is about 5 lbs., which of course makes it very difficult to play. To obviate this trouble, Mr. Barker invented what is known as the *pneumatic lever*, the first application of which was made by him on the organ in the Church of Notre Dame at Bordeaux, built by Cavaille-Col in 1844. The pneumatic lever has for its object not only to lighten the touch of the manual to which it is attached, but also to operate the couplers, so that when the organist couples one manual to another the touch is not increased, all the work being done by the lever. It may be briefly described as follows: It consists of a set of small bellows, one for each key, each being about 12 in. long and 3 in. wide. In each bellows is a small valve which will allow compressed air instantly to

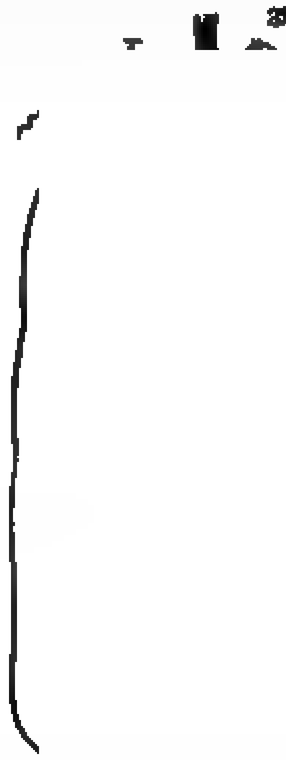
enter when the valve is opened. When the organist presses a key, he opens this valve and closes another valve which is on the outside of the bellows. The latter then becomes inflated, and remains so until the key is released, when the valve on the outside is opened and the air is allowed to escape. Suitable mechanism is attached to the top of the bellows, and from thence to the valves and couplers. The inflating of the small bellows pulls open the large valves in the organ and operates the couplers also. The time occupied in inflating the bellows is not found to be long enough to cause any appreciable retardation in the speaking of the pipes. There are several other devices for lightening the touch of the organ; among others the electric action, which however is not necessary where the keys of the organ are located near the other mechanical parts.

The Electric Action devised by Mr. Hilborne L. Roosevelt is represented in Figs. 3312 and 3312 A. *A*, Fig. 3312, is the wind-case in which the bellows compresses the air, and *C* is the valve to be opened, over which the pipe to be sounded is placed. This valve is attached to a kind of small bellows *D*, the top surface of which is a little larger than the valve *C*, while the interior of this bellows connects by the channel *G* with the compressed air in the wind-chest *A*. The arrows around the small valve *E* indicate the course of the wind when entering this inner space *G D*. When the valve *E* is closed by pressing it downward, this communication of air between *A* and *G D* is interrupted, while at the same time another valve under *E*, and attached to the same stem, opens and gives exit to the air in *G* and *D*. The upward pressure in the small bellows *D* being removed, the condensed air in *A* presses it down, while the stem connecting it with the valve *C* pulls this down, the greater surface of *D* making the downward pressure greater than the upward pressure on *C*. Instead of thus connecting the key to the large valve *C*, it is connected to the rod passing through the

3312.



3312 A.



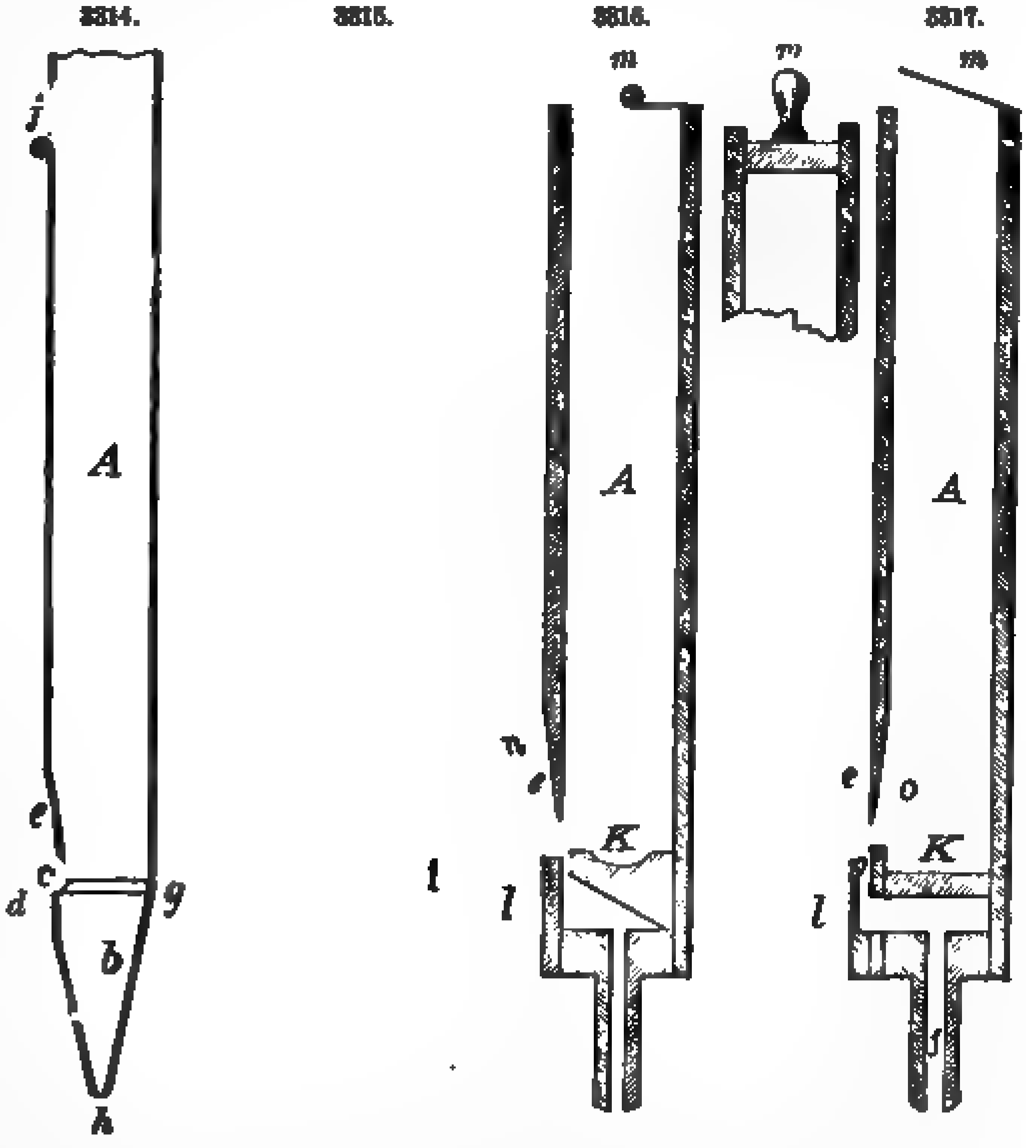
two valves *E*; notwithstanding this apparently roundabout way, the motion of the valves is so rapid as to respond to the utmost velocity of execution of the organist. In regard to the pipes operated by the application of electricity, all that is required is to connect the rod passing through the valves *E* with the armature of an electro-magnet *F*, and to cause the touch of the key on the key-board to close the electric current and charge this magnet, when at once the armature will be attracted, pull the rod, and shift the valves *E*, when the air in *G D* will escape, the bellows *D* collapse, the large valve *C* open, and the pipe standing over it sound. When the finger leaves the key, the electric contact is interrupted, the spring lifts the armature of the electro-magnet *F*, this opens the upper valve *E*, admits the pressure of air in *G D*, raises the top of the bellows, and this at once shuts the valve *C* and stops the tone; all this occurs so rapidly that the time elapsing is imperceptible for all practical musical purposes.

The application of electricity to governing the stops is represented in Fig. 3312 A. *J* is one of the stop-handles. The small bellows *B* is located outside of the chamber, but communicates with it by the passage *C*, in which is a double valve *D*. When the upper part of valve *D* is raised and its lower part closed, there is a free passage for the air to pass from the wind-chest into the bellows; when the valve is lowered, as represented, there is a clear passage from the bellows to the outside air. The stem of valve *D* is connected with an electro-magnet *E*, arranged as previously described. There is, besides, another magnet at *F*, which controls a moving armature *G*, one end of which forms a latch and engages with the armature of magnet *E*. On the top of the bellows are two pairs of springs, one pair *H* being in control only when the bellows is down, the other *I* being in like condition only when the bellows is inflated. On the lower side of *J*, the stop in the organ, is a switch which comes in contact with one or the other of the metal plates *K* and *L*, according as the stop is pushed in or drawn out. The lead of the circuits is first from plate *K* to magnet *E*, thence to the upper spring of pair *I*, and from the lower spring of the same pair to the battery; the second circuit passes from plate *L* to magnet *F* to the lower spring of pair *H*, and from the upper spring of the same pair to the battery. The object is to move the bellows, and this last moves a series of switches oscillating on a horizontal axis so as to establish connection in 58 key-circuits at once. When the

stop is pushed in as shown, there is obviously no connection with the battery, because of the pair of springs I being separated. Supposing, however, the stop to be drawn out, then the switch on its lower side comes in contact with plate L, the current passes and excites the magnet F, which draws back its armature G, and so releases the armature of magnet E, the current of course continuing through the pair of springs H, and so to the battery; but the effect of releasing the armature of magnet E is to raise the valve D, so that, as before stated, the air from the wind-chest is allowed to pass through the passage and into the bellows; the latter then rises, throwing over the 58 switches, and so establishing the connection of the keys. But as this rising continues, the springs H separate, and the circuit is thus broken; at the same time the pair of springs I come in contact. The bellows remain however inflated, because the position of valve D remains unchanged, no circuit being complete through the springs I and magnet E until the stop pushed in establishes connection with plate K; consequently the bellows will stand full and thus push the switches into action as long as the stop beside the key-board is drawn out. When that stop is pushed in, the circuit closes, magnet E is excited, and valve D drawn down, cutting off any further supply of air to the bellows, and opening an escape for its contents. As valve D falls, the catch on armature G slips over the armature of magnet E, and as the bellows descends springs I once more separate, and thus the parts are again brought to the condition as before.

Mr. Roosevelt has made numerous applications of this action to church organs, and has been enabled by its aid to produce many novel and striking effects. The large engraving, Fig. 3313, represents the chancel, gallery, and echo organs. The chancel organ is placed in a chamber built for the purpose, at the angle formed by the east wall of the south transept and the chancel wall. The gallery organ stands at the west end of the church, over the main entrance. The echo organ is situated in the roof, over the intersection of the nave and transept. These organs are connected, by means of electric action, with the key-boards in the chancel, and are thus under the complete control of one performer. A distance of 150 ft. separates these sections from each other, and over 20 miles of electric wire have been used to connect them. The sound-boards are constructed on the exhaust principle, with certain modifications and improvements, by means of which the keys communicate directly with the pipes, the touch being thus rendered easy and at the same time prompt. The same principle governs the draw-stop action, slender trackers serving the purpose of the former heavy rods. The stop action and other accessories connecting with the gallery, though apparently not different from those of the chancel organ, are electric. The composition pedals are so made that the organist may, at option, arrange one or all of them for any set of changes or combinations, from one stop to the full power of the organ. They are double-acting, and operate without affecting the draw-stop combinations made previously.

3314. 3315. 3316. 3317.



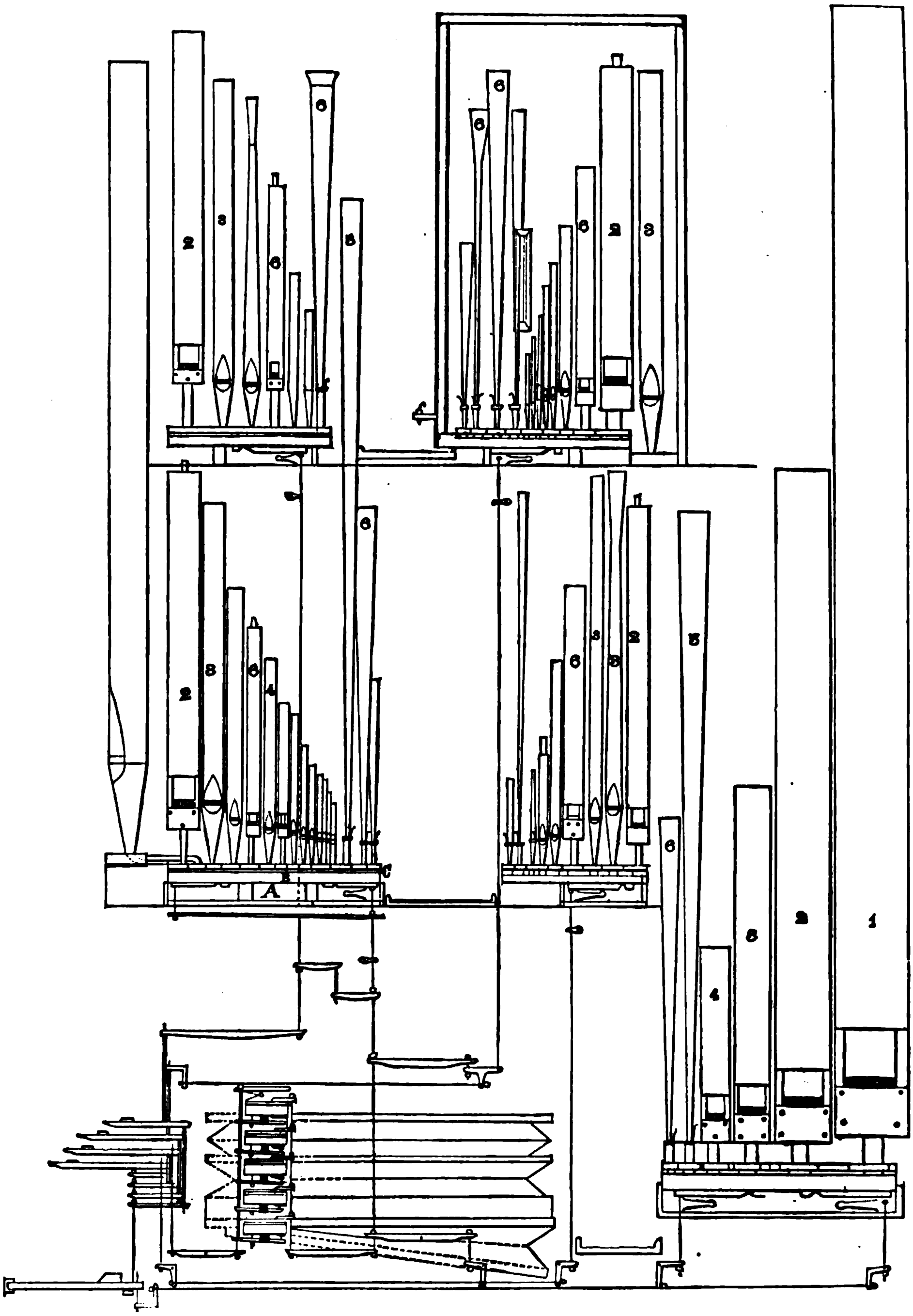
Organ Pipes are constructed as shown in Figs. 3314 to 3317, which represent the pipes used in the flue-stops, in which a column of air vibrates. A represents the body of the pipe; b, the foot for conveying the air; c, the mouth of the pipe; d, the lower lip; e, the upper lip; f, the flue, or air-passage; g, the languette, dividing the body of the pipe from the foot; h, the toe, or entrance of the wind; i, the ears for steadying the wind; and j, the tuner. In the section of a wood pipe the difference is represented thus (Figs. 3316 and 3317): K, the block; l, the cap; m, the tuner; n, exterior bevel; and o, inverted mouth.

Reed pipes are of two kinds, the impinging or striking reed, and the free reed. With the impinging reed the air causes the tongue to vibrate on the flat surface of the eschallott, through which is the opening to the body The vibrating portion of the tongue is lengthened or shortened, and thus made to vibrate slower or faster, according to the desired pitch, by raising or lowering the tuning spring. With the free reed, the tongue does not strike, but is carefully fitted so that it vibrates in the opening on the face of the eschallott. Reed stops produce imitations of the clarionet, oboe,

trumpet, etc. Flue stops (which are the genuine organ stops) give the diapason, dulciana, flute, and the like.

By the scale of a pipe is understood the diameter or dimensions, as compared with its length.

3318.



The diameter of a pipe affects the quality of tone, as does also the height of its mouth. The length of the pipe is doubled for every 13 pipes, giving 13 chromatic tones as in the complete octave. The diameter is doubled every 17 pipes. The pipes vary in length from 32 ft. to three-fourths of an inch.

Giving a proper tone to these different pipes is called "voicing," and herein lies the great art of organ-building, as few men can be found with sufficiently delicate ear and musical feeling to give the proper character to the different stops. The general shape and length of the pipe, of course, are determined mathematically; but this will not insure necessarily the proper speech and character of tone. It is comparatively easy to make a noisy effect with the stops, but to impart the proper character to each pipe, so that when it is played with a full organ there will be a perfect blending of tone, and when it is played separately each stop shall have a character of its own, is a most difficult problem, only to be accomplished by skilled and experienced organ-builders.

The general arrangement of the various portions of a large organ is represented in Fig. 3318, which exhibits the grand organ of the new St. Patrick's Cathedral in New York, designed and built by Messrs. Jardine & Son. *A* is the great-organ wind-chest, *B* is the sound-board, and *C* the registers or sliders. There are four ranks of keys, connected severally with the different parts of the instrument. Thus the lower range operates the choir or soft organ, the pipes of which are of sweet intonation, and are voiced more delicately, with less wind-pressure, than those of the others. The next rank above controls the great organ. These pipes are of large diameter, and have a rich powerful tone. The swell organ is governed by the keys of the third rank. The pipes in this are full-toned, and are inclosed in a swell-box, the vertical shades or shutters of which impede the emission of the sound, and are governed by a balanced pedal. The fourth rank of keys governs the solo organ. In this are placed the trumpet, double trumpet, and other brilliant-sounding pipes, operated by heavy wind-pressure. By means of the couplers all four of these subordinate organs can be united. Besides the organs operated by the keys, there is the pedal organ, the large pipes of which are shown on the right, and which is governed by the feet of the performer.

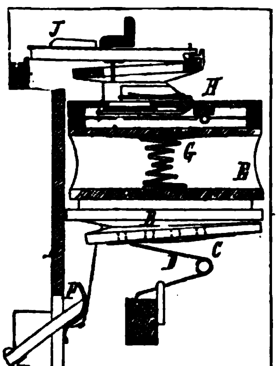
Large Organs.—The largest organ in the world is in Albert Hall, London, and was built by Henry Willis in 1870. It contains 138 stops, 4 manuals, and nearly 10,000 pipes, all of which are of metal. The wind is supplied by steam-power. Thirteen couplers connect or disconnect the various subdivisions of the organ, at the will of the performer. The organ at St. George's Hall, Liverpool, also built by Mr. Willis, has 100 stops and 4 manuals. That of St. Sulpice in Paris is of the same magnitude, and has 5,000 pipes. The largest organ in the United States is in the Music Hall, Boston, and was built by Walcker of Ludwigsburg, Germany. It has 4 manuals, 89 stops, and 4,000 pipes.
G. H. B.

ORGANS, REED. The reed organ belongs to that class of musical instruments in which the tones are produced by vibrations imparted to a body of air in a tube, throat, or chamber by means of the pulsations of a thin lamina or tongue of wood or metal, having one end fixed and the other lying over or within an aperture, and actuated by forcibly directing through this a current of air. This lamina is termed a reed. There are two forms of reed. In the first, seen in the clarionet, the reed is larger than the opening through which the air is to pass, and in pulsating alternately closes and opens it, beating against its margins. This form is known as the beating reed. In the second, seen in the accordion and modern reed organ, the dimensions of the reed are slightly less than those of the aperture, so that, in pulsating in consequence of an impulse and of its own elasticity, it moves within the current of air only, alternately allowing and interrupting its passage; it is hence termed the free reed.

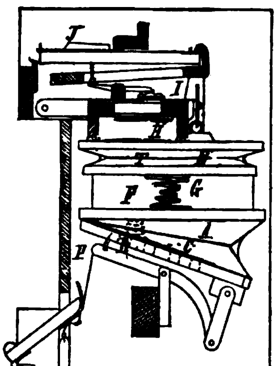
The reed organs, or as they are more commonly termed cabinet organs, made in the United States, are with few exceptions in their essential features strictly of American origination. They differ from European instruments known as "harmoniums" in several particulars, nearly all of which however are subordinate to two leading ones, which are: 1, the kind of bellows employed to force air through the reeds; and 2, the method of voicing the reeds.

THE BELLOWS.—Up to about the year 1846, when the suction or exhaust bellows was devised, the

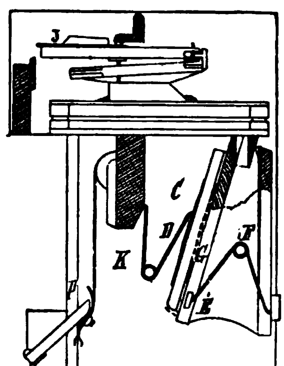
3319.



3320.



3321.



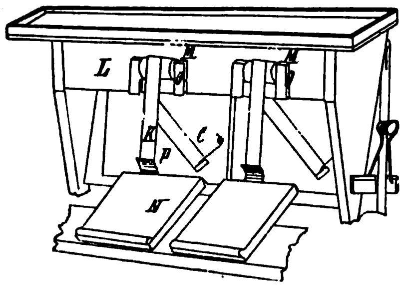
blowing or pressure bellows had been the only form in use. The peculiar features of these two types of bellows are represented in Figs. 3319 and 3320. *A* represents one of the feeders, *B* the breathing-holes shown in dotted lines, *C* the feeder-valve, *D* the feeder-spring, *E* the reservoir, *F* the reservoir-spring, *G* the intermediate valve, *H* the reeds, *I* the reed-valves, and *J* the keys of the instrument. The parts are shown in nearly a normal position, the slight deviation therefrom being

simply to make them more clearly visible. It will be observed that in Fig. 3320, which represents a harmonium, the normal position of the feeder *B* is open or distended, and the reservoir closed or contracted, while the reverse is the case in Fig. 3319, which is a cabinet organ. In Fig. 3320 the spring *D* and the valve *C* are inside the feeder; the spring *F* is outside the reservoir, so as to press it upward; the valve *G* is inside the wind-chest, arranged to open upward, and to close at the proper time to prevent the return of the air to the feeder; and the reeds *H* are also inside the wind-chest. In Fig. 3319 these features are also all represented as reversed. In the harmonium, Fig. 3320, the air is breathed from the lower body of the case, through the holes *b*, and is blown or forced upward and into the wind-chest and reservoir, and thence through the reeds to the top of the instrument. In the cabinet organ, Fig. 3319, the air is drawn or sucked through the reeds from the wind-chest and reservoir, and escapes at holes *b* to the lower body of the case. The distention of the reservoir of the harmonium is caused by the air being forced or pumped into it, and its contraction by the spring *F*. The distention of the reservoir of a cabinet organ is caused by the spring *F*, and its contraction by the air being drawn or pumped out of it. The power of the harmonium reservoir is greatest when it is distended to its fullest. The power of the reservoir of a cabinet organ is greatest when it is fully contracted.

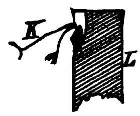
Figs. 3319 and 3320, while differing in principle, are both represented as horizontal and of the same form, for convenience of comparison. Fig. 3321 represents in elevation the exhaust bellows and other parts now in common use. It is the same in principle as Fig. 3319, and differs from it only in form or the arrangement of the parts. Fig. 3322 is a front elevation of part of Fig. 3321.

Bellows Mechanism.—The mechanism used for operating the bellows in the Mason & Hamlin, the Estey, and other well-known organs, is illustrated in Figs. 3321 to 3324. *K* is a strip of girth-webbing, one end of which is fastened to the feeder *B*, as shown in section in Fig. 3323. It passes through an opening in the support-bar *L*, and rests on the roller *M*, and is attached by its other end

3322.



3323.



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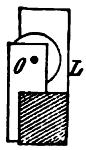
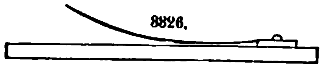


3325.

3326.



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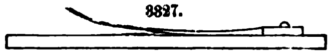

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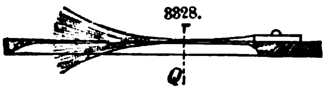

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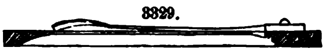


3330.

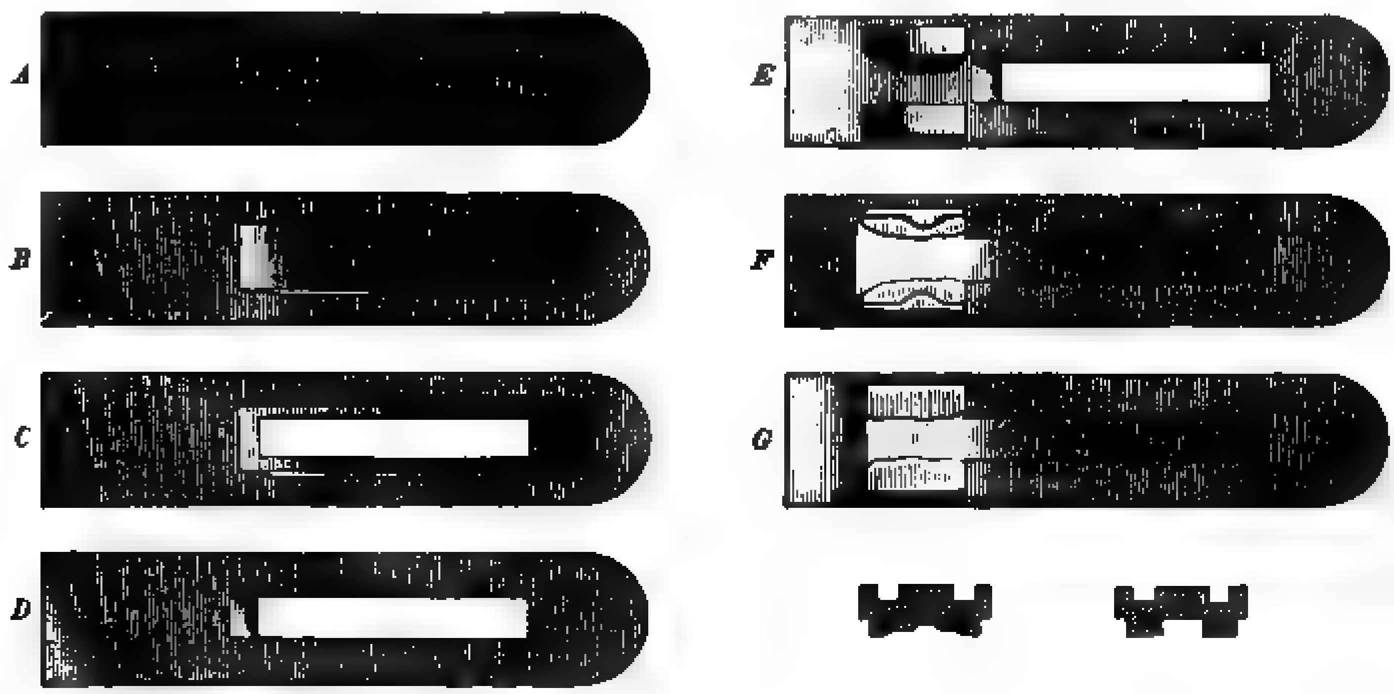
to the pedal *N*. The manner of the operation is obvious. The objection raised to this method is that the straps wear out, but that is claimed not to be the case when they are made of good flaxen stock. In the Peloubet & Pelton organ illustrated farther on, this webbing is done away with, and the bellows is moved by rods connecting with the treadles.

Reeds.—Fig. 3325 represents a reed formed and voiced according to the modern system. The essential conditions of a properly full-voiced reed are: 1. The tongue must be of a thickness consistent with promptness of speech. 2. It must be evenly filed, and so that when bent up by the finger it will have an even graceful bend, as in Fig. 3326. Fig. 3327 represents an unevenly filed reed. 3. The bend should start from about two-thirds of the distance from point to heel (*Q*, Fig. 3328). 4. The bend and twist forming the curve of the tongue should bear such relation to each other as will provide that the under face of the tongue at the highest point of the bend *R* on the right (the back of the figure) and the under face of the tongue at the point *S* on the left will both, on being depressed, be level with the upper face of the block at the same time. Partial voicing by a "short bend," as in Fig. 3329, is easier done, because, if there should be any slight imperfection in the shape, there is enough of the tongue left "straight" to secure passable promptness of speech. 5. The tongue should be about twice as thick at the butt as at the centre. Fig. 3325 fairly represents the required proportions. 6. The tongue of the reed must be firmly fastened to the block. In Needham's reed the tongue is secured by two brass rivets forced in and upset at the same time In the Munroe reed no rivets are used, the metal being struck up and compressed around the base of the tongue, as described further on. In the Mason & Hamlin organ the sides of the block are made in the shape of a V, as in Fig. 3330, the advantage claimed being that the block will conform easily to any ordinary inaccuracy in the tube-grooves, and be securely gripped by the wood. Other makers prefer a square-sided block, which has the advantage of always resting in the groove firmly, despite changes in form of the cell.

The Munroe Organ Reed.—The main difference in the construction between the reed manufactured

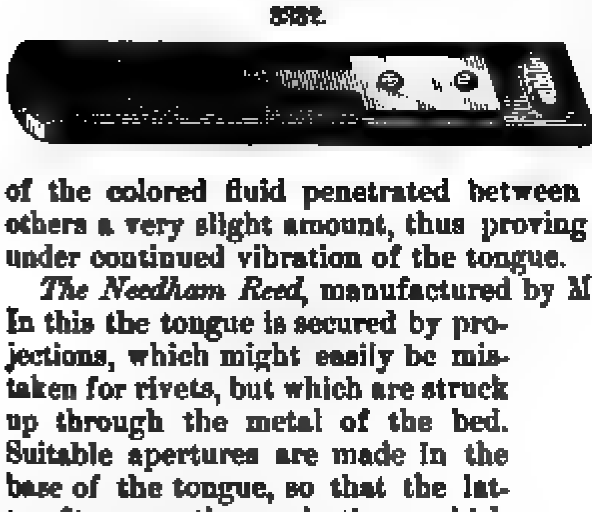
by the Munroe Organ Reed Company, of Worcester, Mass., and other reeds, lies in the method of securing the tongue or vibrator to its seat on the block. This will be understood from Fig. 3331, in which the principal stages of the manufacture of a reed are represented. *A* is the blank, cut out of brass and having its edges nicely planed. In this is formed the indentation shown in *B*, and

3331.



through the latter the throat-opening is cut, as exhibited at *C*. Turning the reed over, the next step is to cut the notch or bevel represented on the left of the throat in *D*. At *E* are shown two projections raised on the body of the reed, and in the inner edges of these a groove is planed into which the tongue is fitted. By means of a press a thin edge of metal is first brought down over the tongue, as shown at *F*, so as firmly to clamp it in place, and then the final pressure squeezes the remaining metal of the projections firmly against the sides of the tongue, closing all parts down upon the bed. Tests of the tightness of this joint have been made by inserting reeds in a solution of aniline in alcohol, and noting whether any of the colored fluid penetrated between tongue and bed. In most cases none was found, and in others a very slight amount, thus proving that the joint is exceedingly firm and not liable to yield under continued vibration of the tongue.

3332.



The Needham Reed, manufactured by Mr. E. P. Needham of New York, is represented in Fig. 3332. In this the tongue is secured by projections, which might easily be mistaken for rivets, but which are struck up through the metal of the bed. Suitable apertures are made in the base of the tongue, so that the latter fits over the projections, which are then pressed down or expanded, thus holding the tongue in place.

3333.

Figs. 3333 and 3334 represent plan and sectional views of the sound-board and tubes used in the Needham organ. The shape of the tubes or chambers is clearly shown in Fig. 3334. A peculiarity of this board is that the grain of the wood all runs the same way; and in this respect it differs from boards of other makers, in which the grain of the piece above the tubes runs at right angles to that of the board below.

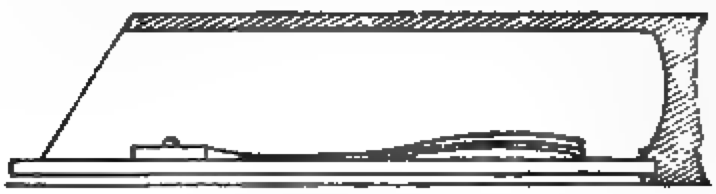
The Mason & Hamlin Reed, represented in Fig. 3326, has its tongue secured by one iron rivet if the reed be small.

3334.

Tubes.—The first requisite of a tube, Fig. 3335, is that its mouth shall be at least large enough to admit all the air the reed inserted in it is capable of carrying. This condition being provided, the tube for the lowest bass note, F, may be half as long again as the tongue of the reed. In common practice the tube for lowest F is not more than about a quarter of an inch longer than the tongue.

Stops and Action.—Fig. 3336 represents in sectional elevation a part of one end of a Mason & Hamlin cabinet organ, with stop mechanism and reed-valves mounted thereon. Fig. 3337 is a sectional elevation representing auxiliary mutes. Fig. 3338 is a front elevation showing the manner in which the stop-valve is mounted. U represents the wind-chest, I the reed-valves, T the stop-valves, V (Fig. 3336) the swell-cap with the swell-lids W attached to it, X the stop-lever, b' the transverse roller-lever, c' the roller-board (the board on which the transverse levers are mounted), a' the name-board, a and b the stop-draws, and R the tube-board. Fig. 3339 also represents some of these parts. The inner end of the stop-valve T is attached to the face of the tube-board R by a small butt-hinge c. One half of a similar hinge d is fastened to the tube-board near its outer end; the stop-valve T is attached to this half hinge d by the bent wire e. A connection is made between this bent wire e and the stop-lever X by the link or toggle y. On the upper side of the stop-lever X is mounted a brass incline g. The transverse lever b' consists of a rod of wood, having at each end an arm, one of which connects with the stop-draw a or b, while the other engages with the incline g. Pins are driven into both ends of the transverse lever-rod, which form pivots upon which to rotate in the

3335.



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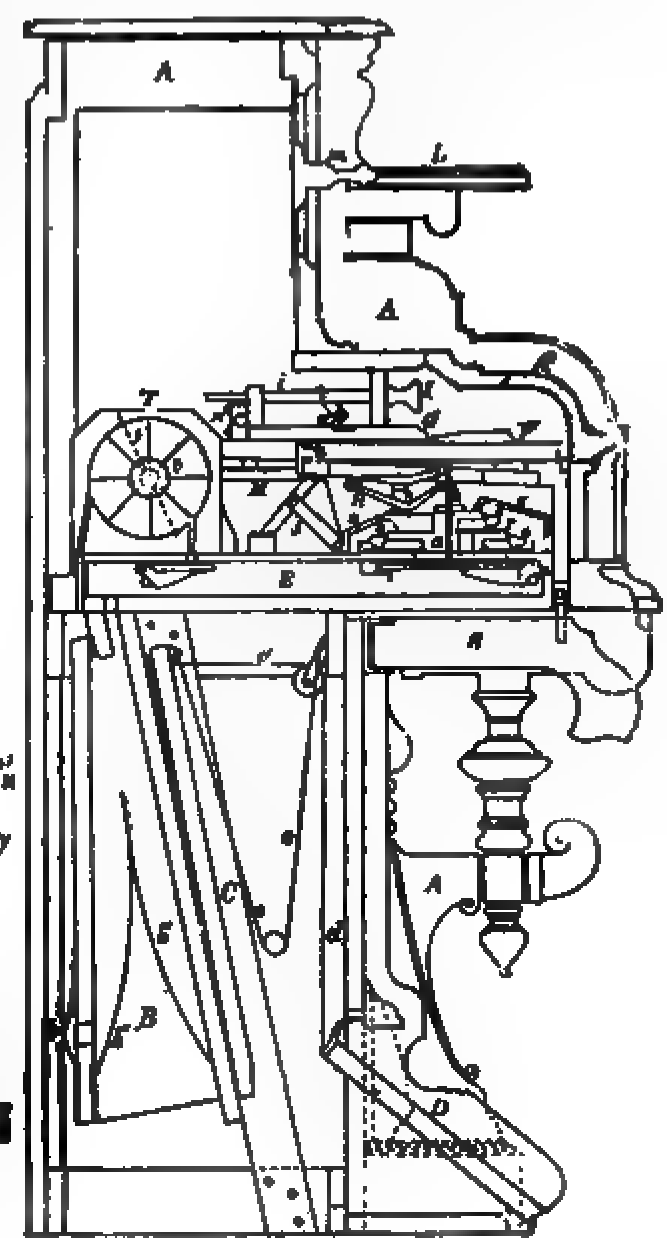

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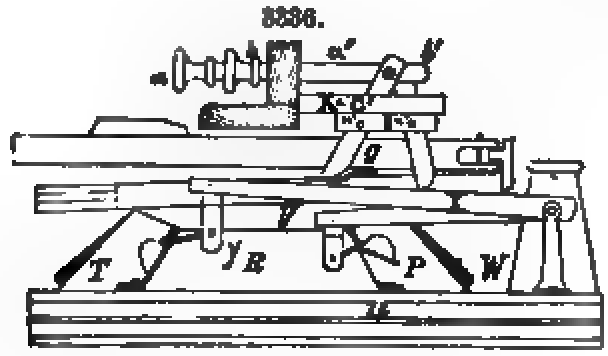


3337.

3339.

3340.

blocks x'. The stops represented in the figures are duplicates of each other. One of them is drawn, or out, and is represented as being connected with the valve P at the back of the tube-board R.

After the closest fit possible in the ordinary processes of manufacture, and consistent with the free action of the stop-valve, has been made, more or less air will rush into the tubes, and, without some auxiliary provision, will cause the reeds to "whistle." The tongues of high-pitched reeds, beginning about second F above middle C, are necessarily so closely fitted to the blocks that, in the relation between the two, a kind of accidental "languid" will form which, as the air passes through it, produces the disagreeable effect named. There are in cabinet organs, substantially, only two methods for overcoming this difficulty. One of these is to "bleed" the tube, by making a hole or air-passage beyond the reed, and from the tube into the valve-chamber, as in Fig. 3338. This hole is large enough to carry all the air that under any ordinary conditions might rush into the tube, so that the reed is perfectly muted. This method under ordinary pressure is effective and cheap. Another method, which effectually mutes the reeds without leak-holes, is represented in Fig. 3337. f represents one of a series of levers hinged at one end by a leather strip, and held down by a spring. Flexibly suspended from its centre is a peg f'. When the stop-valve is closed, this peg rests on the reed; when it is open, the peg is away from the reed.

THE PELOUBET AND PELTON CABINET ORGAN.

3343.

B

The means for controlling the passage of air from the reeds consist of the valves *I*. As these, in all ordinary instruments, are mounted inside the wind-chest, they are difficult to reach; hence it is important that they should be strongly constructed and self-adjusting. Figs. 3339 and 3340 represent, in elevation and plan views, a valve which is used in the Mason & Hamlin organ.

The Estey Organ.—The construction of the cabinet organ manufactured by the Messrs. J. Estey & Co., of Brattleboro, Vt., is represented in section in Fig. 3341. The letters refer to the following parts: *A*, case; *A'*, lid to key-board; *B*, bellows-reservoir; *b*, escape-valve; *b'*, receiver-spring; *D*, treadle; *d*, tape connecting *D* with *C*; *E*, wind-chest; *a*, reed-socket; *r r*, reeds; *e*, dampers; *s*, swells; *H*, octave-coupler levers; *h*, tracker-pin; *F*, key; *G*, name-board; *I*, stop-knob; *i*, stop-rod; *J*, lever and link for raising swells; *M*, slide for opening dampers; *n*, grand-organ roll; *T*, vox humana tremolo; *t*, float-wheel of tremolo; *f*, fan; *m*, music-support; *L*, lamp-stool; *S*, knee-swell lever.

3344.

The Peloubet & Pelton Organ.—This organ, manufactured by Messrs. Peloubet, Pelton & Co., of New York, is illustrated in the full-page engraving, Fig. 3342, and in Figs. 3343 to 3346, which are drawn to perspective in order more clearly to exhibit the general mode of putting together an organ of this class. The reader will easily perceive the points of difference between this instrument and that of Messrs. Mason & Hamlin, which served as a model for the explanation of the essential features of all reed organs.

Fig. 3342 represents the organ in its case, and Fig. 3343 shows it removed. The left-hand blowing pedal of the bellows is down, and its corresponding pumping valve is drawn forward by the connecting-rod. This rod gives a direct action, and is peculiar to this form of organ, taking the place of the roller and strap used in others. The pumping valve is returned to its place by its spring, the loose end of which is fastened to the front panel of the case. The effect of the pumping valves, when operated by the feet, is to exhaust the bellows, upon which the required pressure is produced by the spring and its mate at the right. At the right and left of the front are seen the ends *A* of the mutes belonging to two full registers of reeds. On the top, back of the keys, is the stop-board *B*, with its knobs in front. It is made wide so as to afford a firm bearing for the levers seen in Fig. 3344, which shows the stop-board in reverse. These levers are carefully finished, have washers at their centres, and have their ends covered with rubber tubing to prevent noise.

Their ends fall into the forks of the upright forked levers *C*, Figs. 3343 and 3346, the effect of all which is to give a direct motion to the forked levers with their connections that open the mutes *A*, while at the same time each mute is left free to be operated separately or in combination with others. The sub-bass is peculiar to this organ both in its position and the manner in which it is built up. Its register of reeds is placed under the action. Each reed has its heel to the front of the case, so that it can be drawn out under the plinth. Reeds of large size, producing tones of 16 ft. pitch, are placed in very deep cells which afford room for vibration. These cells, with the levers operating the pallets of this set of reeds, are shown in Fig. 3345. The levers are drawn together in front to bring them under an octave of the key-board G. H. B.

ORGANZINE. See Silk-spinning Machinery.

OVEN. See Bread and Biscuit Machinery.

PADDLE-WHEELS * are circular frames carrying floats, buckets, or paddles, so arranged as to propel a vessel by their action upon the water. The commonest form of paddle-wheel is represented in Fig. 3347. It consists of two centres and two sets of concentric wrought-iron rings, which are joined to the centres by a number of radial arms. These two sets are placed at a fixed distance apart on the shaft, and the buckets or floats are attached to the arms near their outer ends, thus connecting the rings. Stays are also run across between the arms, so as to give the whole structure greater firmness. When such a wheel revolves, the floats strike the water and tend to push it back; but the water resists such an action on account of its inertia, and therefore the vessel to which the wheel is attached must move forward.

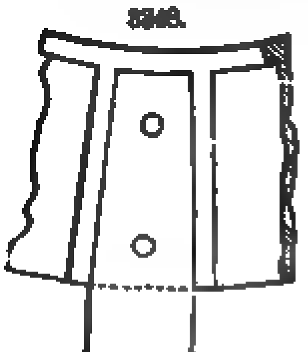
3347.

Figs. 3348, 3349, and 3350 represent the usual methods of attaching the arms of paddle-wheels to the centres. In Fig. 3348, the centre consists of a cast-iron plate, to which the arms are bolted in sockets cast therein for the purpose of preventing lateral motion. Fig. 3349 shows a method of inserting the arms in a mortised plate and securing them by keys. In Fig. 3350 the ends of the arms are so shaped as to fit together at the centre, and are riveted to a plate of boiler iron. Fig. 3351 represents the usual mode of securing the arms to the inner ring. A lug is welded on each side of the arm, and through these lugs the arm is riveted to the ring.

The floats for radial paddle-wheels are usually made of pine or elm, 2½ to 3 in. thick. White oak and ⅜-inch boiler iron are also used. After the floats have been attached and the wheel is worked, it is necessary to examine the screws or bolts occasionally, and to draw them up tight, as they are liable to work loose after a while, and then there is danger of the floats being washed off the wheel. The floats are frequently attached by means of hook-bolts, so as to enable the engineer to adjust the depth to which they dip in the water, as a part of the float may drag if not immersed to the right depth; and also a shifting or reefing of the floats may give a better result.

Disengaging Paddle-Wheels.—It is frequently desirable to be able to disconnect one or both paddle-wheels from their shaft, so that they may revolve loosely. Figs. 3352 and 3353 represent a

3348.



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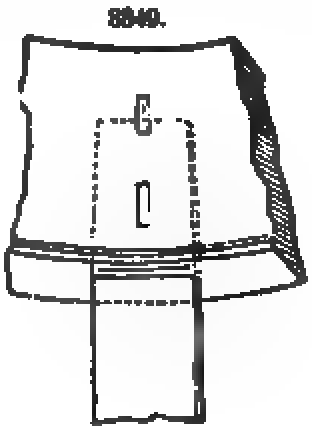

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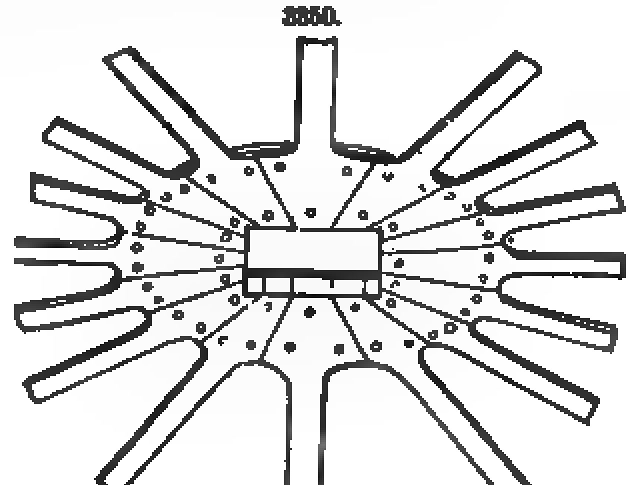

device for this purpose. *A* is the paddle-shaft; *B*, a cast-iron disk keyed thereon; *C*, a wrought-iron strap surrounding the disk, lined with brass; *D*, a brass cushion with a tightening key for producing friction by bringing the cushion in contact with the disk; *F*, the brass lining of the wrought-iron strap, excepting that portion covered by the cushion; *f f*, screws by which the lining is held to the strap. A few blows of a hammer on the key *B* serve to connect or disconnect the shaft.

Feathering Paddle-Wheels.—There is a loss of useful effect attending the use of any of the kinds of paddle-wheels described above. This loss arises from the fact that the floats or buckets strike the water obliquely, and therefore do not apply all the power in propelling the vessel, but use up a portion of the same in lifting the vessel when the wheel enters the water, and lose another portion

* Prepared by A. Sorge, Jr., M. E., under supervision of Richard H. Buel.

in raising some of the water when leaving it, and creating a swell. Frequent attempts have been made to obviate this difficulty by making the buckets enter the water edgewise, travel through the water in a vertical position while immersed, and leave it edgewise again. To do this, the buckets must assume different positions with regard to the wheel while revolving, and this action has been

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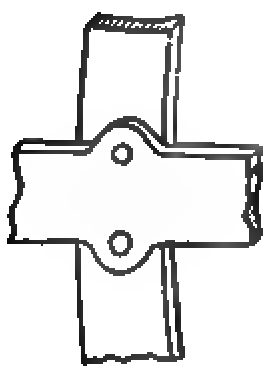

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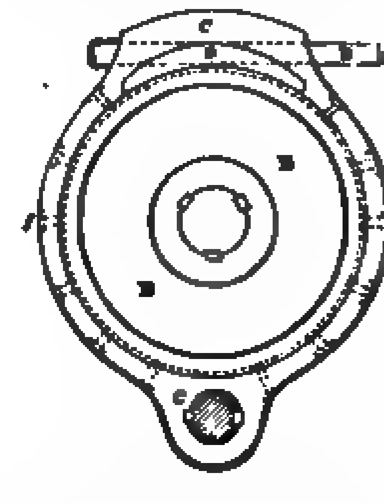
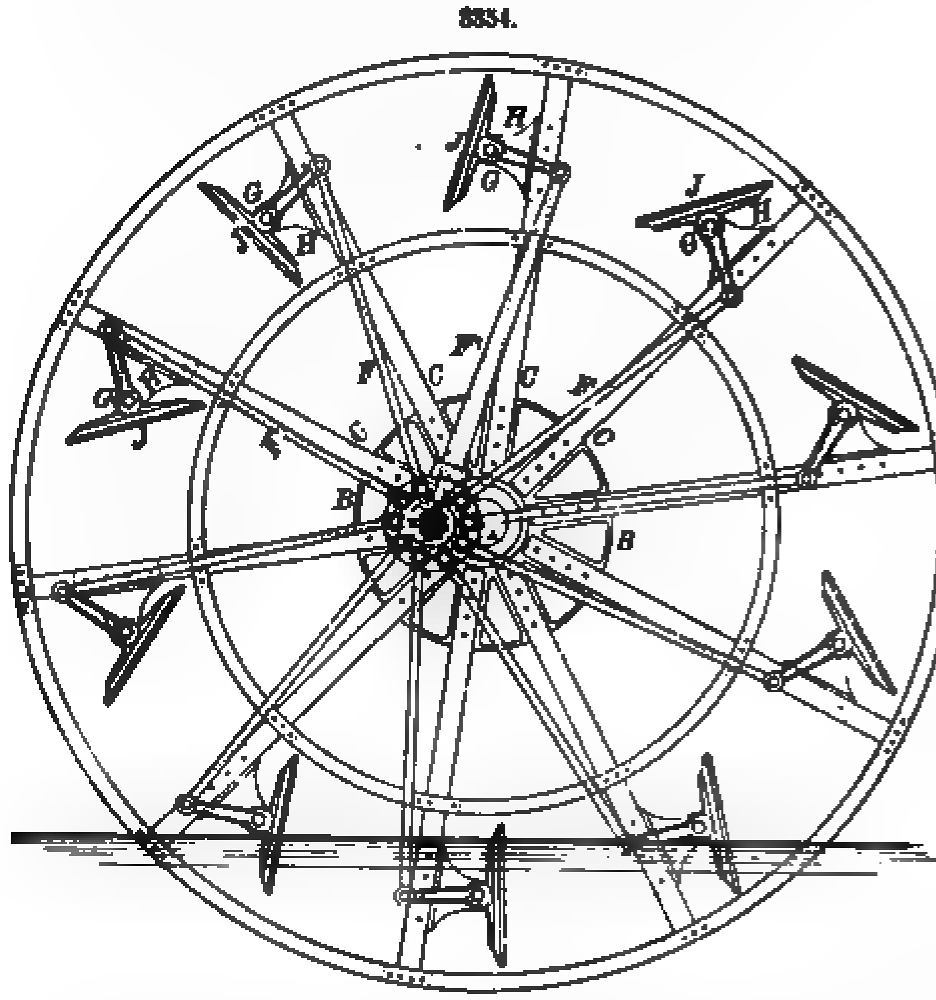


called feathering. Numerous arrangements have been proposed and tried in order to effect this purpose, many of which failed on account of the complication of the parts and their liability to get out of order. We here illustrate a feathering paddle-wheel which has been in successful operation since May, 1877.

Figs. 3354 and 3355 are a side view and section of the feathering paddle-wheel of the steamer Accomac, of the Old Dominion Steamship Company, built at the Morgan Iron Works, New York. It has two sets of rings of 3 × ½-inch iron. The largest diameter of the outside rings is 16 ft. 6 in., of the inner rings 9 ft. 10 in.; clear width between rings, 3 ft. 11½ in. Two cast-iron centres *B B*, 4 ft. 6 in. diameter and 10 in. bore, have bearings on shaft *A* of 6½ in. length each, and are spaced 18½ in. apart in the clear. The rings and centres are joined by two sets of arms *C* (10 in each set), which are riveted inside the rings and on the outside of the centres in recesses cored out for that purpose, as shown in the views. They are 4½ in. wide and ½ in. thick. The two sets of arms are connected and stayed by means of bent flat iron bars ¾ in. thick and 3½ in. wide, riveted to the arms inside the inner ring, and also to the inner surface of the centres *B B* at recesses cast on for that

3354.



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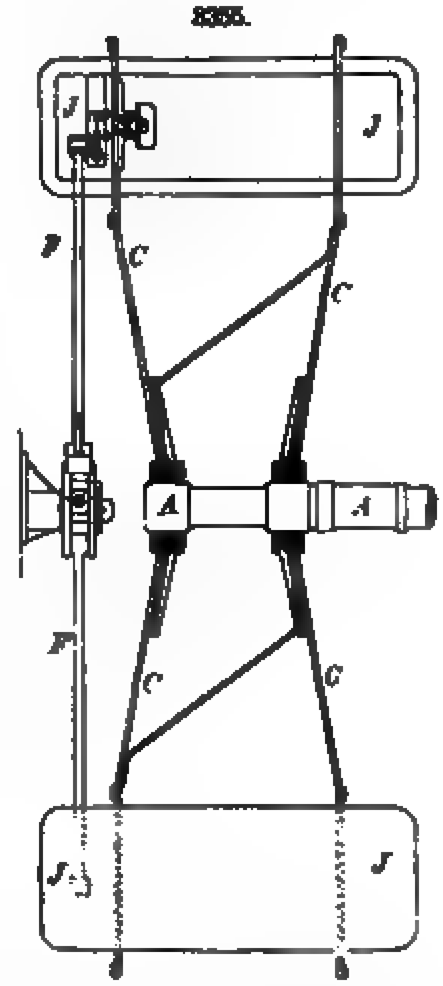

purpose. The centres have two wrought-iron hoops of 1½ × 1½-in. iron shrunk around each. There are 10 buckets, *J J*, 30 in. deep by 6 ft. 6 in. wide, which are fastened to the arms by means of brackets *H*, having bearings for the trunnions to turn in, thus holding the buckets, which swing around these trunnions in their relative positions while allowing them to turn or feather. The

buckets are attached to the trunnions by the cranks G, which in their turn connect with the eccentric E through the eccentric-rods F (1¼ in. diameter), which can oscillate around pins in E, and also around pins connecting them with the cranks. F' only cannot oscillate in E, and this gives the eccentric a positive motion. The last-named rod is made of 1½-in. flat iron, and tapers from 4½ to 2½ in., being keyed into the eccentric. The eccentric E is placed upon a fixed pin, which is attached to the frame of the paddle-wheel box by means of a casting shown in the section. The trunnions of the buckets are 6 ft. 7 in. from the centre of the wheel. The eyes of the eccentric-rods F, the bore of eccentric E, and the bores of brackets G are lined with lignum-vitæ, and all pins having working surfaces are covered with hard brass. The buckets (10 in number) are made of white oak, and are 2½ in. thick, of the shape shown. The wheel, revolving with the shaft A, turns the buckets; and F' being connected rigidly to the eccentric E, it is revolved also. The centre of E is 11 in. from A and ½ in. below it. This position of the eccentric, and its connection with the buckets, turns the buckets through the medium of the eccentric-rods and cranks, as is shown by the positions of the various buckets in the side view, and thereby produces the action called feathering—i. e., making the buckets enter and leave the water in a nearly vertical position, and guiding them in a direction approximately horizontal while immersed, whereby the loss of effect from oblique action, as well as from the blow upon and the lifting of the water, is avoided. The steamer Accomac, which is propelled by two paddle-wheels of the kind described, measures 145 ft. between perpendiculars, 25 ft. beam, and 9 ft. depth of hold, drawing 4 ft. 9 in. of water. The paddles are immersed to a depth of about 26 in. They are driven by a beam-engine of 32 in. diameter of cylinder and 6 ft. stroke, making from 33 to 37 revolutions, and working with a steam-pressure of 40 lbs., cut off at one-third of the stroke. Its boilers are of the flue and return tubular kind, having 42 sq. ft. of grate surface and about 800 sq. ft. of heating surface. The superintending engineer states that the steamer runs at an average of 13 knots an hour, and that the consumption of coal for a run of 80 miles is 2 gross tons, including the firing up, etc.

Feathering paddle-wheels have been made according to Taylor's patent, in which the buckets are kept vertical throughout the whole revolution, being attached by pins to a ring of the same diameter as the wheel, but placed out of centre vertically by the width of the bucket and held there by friction-rollers.

In 1861 a paddle-wheel without buckets was used, and propelled a small vessel very well. It consisted of a series of plain disks of metal placed at intervals beside each other on the paddle-shaft. The action was evidently dependent merely upon the friction of the water against these disks.

Numerous other kinds of paddle-wheels have been invented at various times. In some of them the buckets are not parallel to the axis of the wheel, but inclined to it, and a certain area of acting surfaces is thus always immersed, making the action more uniform and without shocks. In others the floats are continuous and run obliquely around the wheel, crossing each other at various points. Great advantages have been claimed for each one of these wheels, but none of them have found their way into general use.

Stern Paddle-Wheels.—All the wheels described act at the sides of vessels; but there are also other kinds, such as the stern-wheels which are situated behind the vessel. These are employed on the western rivers of the United States, where the water is shallow, and the channel in which boats can run is often narrow. The construction of the wheels proper for this class is the same as for side-wheels, except that their width is made double that of one side-wheel; and the fundamental difference in the method of propulsion is merely in the application of the power, the form of the steam-engine being different.

Designing of Paddle-Wheels.—In order to find the area of a float of a feathering paddle-wheel, we may use the following formula (see Perry's "Treatise on Steam," page 327): Area of the float $= \frac{R\,A\,v^2}{m\,u\,(u - v)}$; where u is the velocity of the centre of resistance of the float with reference to the vessel (expressed in knots); v is the actual velocity of the vessel in knots, and therefore $u - v$ is the slip, which may generally be assumed at about 20 per cent. of the speed; m is the mass of a cubic foot of water, $= 2$ for salt water and $= 1.97$ for fresh water; R is a coefficient depending upon the vessel; and A is the area of the greatest immersed cross-section of the vessel. In Rankine's "Ship-Building" we find the same rule, except that A is the so-called augmented surface in his rule, which is found by considerations given in that book, and R is a constant varying from .008 to .011 and upward, according to the vessel. When the area of floats is to be determined for radial wheels, we take (according to Mr. Napier, *Transactions of the Institution of Civil Engineers of Scotland*, 1863–'4) u to be the velocity of the outer edge of the float instead of the centre of resistance, and we must also allow for various immersions of the vessel.

In the above formula the numerator gives the *resistance* of the vessel in pounds. The *centre of resistance*, or centre of pressure, as it is sometimes called, is that point in the float which would produce the same effect if all pressures were united there, at right angles to the radius, as the pressures actually are by being distributed over the whole area. The determination of this point depends upon the so-called *rolling circle*, i. e., a circle of such a radius that every point in it moves backward (while revolving) as fast as the vessel moves ahead. The centre of resistance is always below the middle point, being higher for deep immersions, but never very far from the centre of the figure in well-constructed wheels. Its determination may also be found in Rankine's "Ship-Building." The *slip* of a wheel is the amount of motion lost by the water not being a rigidly fixed body; it is therefore equal to the velocity given in a backward direction to the water, and is the difference between the velocity of the float and that of the vessel.

The theoretical working of a radial paddle-wheel and the effect of oblique action are considered by J. D. Van Buren in an article published in the *Journal of the Franklin Institute*, 3d series, vol. xlix.,

and also by Prof. R. H. Thurston in vol. lix. These theoretical considerations, however, do not give reliable results, probably because it is almost impossible to determine the exact conditions of action, and because a number of the quantities involved depend upon experiment and vary continually for different wheels and vessels.

PANELING. See CARPENTRY.

PANELING MACHINE. See MOULDING MACHINES.

PANS. See AMALGAMATING MACHINERY, DAIRY APPARATUS, and SUGAR MACHINERY.

PAPER, MANUFACTURE OF. The fibre of an Egyptian plant, the *papyrus*, was first used in the manufacture of paper; hence the name. Rags take the precedence of all other materials in amount consumed in the manufacture of paper and value of the product. The other materials of commercial importance are waste paper, cotton-waste, straw, wood, manilla, jute, esparto, and cane. All of the finest papers are made from rags. The other materials are used in combination with rags, or with each other, or alone for lower grades.

The art of paper-making consists in the separation of the raw material into its primitive fibres, and the recombination of those fibres into felted sheets. The several processes are: 1. The sorting of the materials according to their kinds and qualities; 2. The mechanical separation of all foreign substances and impurities; 3. Cleansing by boiling, the use of chemicals, and by washing; 4. The reduction to fibre by rubbing, the presence of water forming pulp; 5. Bleaching; 6. Coloring; 7. Sizing; 8. The formation of the pulp into sheets or into a continuous web; 9. Surface-sizing; 10. Drying; 11. Calendering, or surface-finishing. The details of these several processes vary somewhat according to the materials used. Their general features are analogous. The subject will be best presented by following out in detail the several steps in the manufacture of paper from rags, and then noting the points of difference when other materials are used.

PREPARATION OF PULP.—*Sorting.*—Rags are sorted by dealers, according to their fibres, into linen, hemp, cotton, manilla, half-wool, woolens, etc.; according to colors, into whites 1st, 2d, 3d, grays 1st, 2d, 3d, blue, red, black, and all dark colors. Paper-rope, bagging, canvas, twine, etc., are classed separately. The condition of the stock, as clean, strong, old, rotted, worn, is also noted. The classification is now so complete that the paper-maker can purchase the goods he wishes for his particular kind of paper. Arrived at the mill, if the rags are very dirty, they are passed through a *duster*, hereafter described. If clean, they are passed to the *sorters*, usually women, who stand at a table about which are baskets or boxes, one for each of the grades into which the stock is to be separated. The top of the table is covered with wire cloth; the frame supports a knife which inclines a little from the perpendicular, and against this knife the rags are drawn and rapidly torn into lengths and cut transversely into squares or pieces as small as can readily be grasped by the hand. During this operation the rags are inspected, foreign substances removed, seams opened to dislodge the dirt, and buttons and buckles cut off. The dirt falls through the sieve or wire cloth into the box beneath, and the rags are tossed into their proper compartments. The sorted rags are passed to the *looker-over*, who inspects them, and returns them to the sorter if the work has been slighted. Only the rags for the finest grades of paper are cut by hand; all lower grades are cut by machinery.

Rag-Cutters.—In all the cutters the knife-edges incline to each other while cutting, to give a "draw-cut." In some machines the cutting blade moves perpendicularly in guides. In others a number of them are set radially about a revolving shaft, the blades moving in a plane at right angles to the feed-box. A third form, which is in common use, has its knives secured to a cylinder of cast iron, which is in front of and parallel with the stationary bed-knife. The blades are set at such an inclination to the surface of the cylinder in which they are bedded, and to the bed-knife, that they become self-sharpening. The rags are fed into the feed-trough by hand, or spread upon an apron which carries them up to a feed-roll. The knives revolve at a constant speed of about 100 revolutions per minute. The size to which the rags are cut is regulated by the rapidity of feed. If the rags are to be cut very fine, they are passed through these same machines several times.

Dusting.—The rags pass from the cutter to the dusting machines. Coarse and dirty rags are worked in a *thrasher*, *devil*, *railroad*, or other form of duster. A *thrasher* has a strong eight-sided wooden body with a horizontal shaft provided with a row of iron teeth on each of two opposite sides. This revolves rapidly in a wooden box; at the top of the box, over the centre of the revolving body, and parallel with its axis, is a strong beam also provided with teeth. The bottom of the box is semi-cylindrical, and is formed of strong wire cloth, grating, or perforated sheet-iron plates, through which the dust beaten from the rags can fall into a chamber beneath. A given weight of rags is placed in the box and subjected to beating by the teeth until sufficiently clean, and then removed to give place to another lot. The *devil* or *picker* has a wooden cone 4 to 6 ft. long, having a diameter of 9 to 12 in. at the larger end and 6 to 8 in. at the smaller. This cone is provided with iron pins, which are set spirally to give a side motion to the rags, and which project from its outer surface. It is covered in by wooden planks which conform to its shape. The middle plank bears a single row of teeth. The bottom is like that of the thrasher. There is thus formed an annular space about the cone, into which at the smaller end the rags are fed, and by centrifugal action are moved forward, being well beaten in their course, and delivered at the larger end. The speed of the cylinder is from 200 to 400 revolutions per minute. The *railroad duster* has a number of cast-iron cylinders 14 in. in diameter and 30 in. long, provided with iron pins which are set spirally about the cylinder and project about 6 in. The cylinders are placed on the same level, and their teeth interlock. They all have semicircular wooden covering on top, and the semicircular sieve, grating, or perforated plate beneath. The rags are fed to the first cylinder, and are delivered from cylinder to cylinder until they pass from the machine. The comparatively clean stock, and that which will not bear such rough treatment as is given by the previously described machines, is commonly passed through a revolving cylinder of wire cloth supported by light framework. The cylinder is about 16 ft. long and about 4 ft. in diameter, both ends being open. It is so inclined that the rags fed into one end

may gradually work downward, brushing over the wire until they fall out at the lower end. The cylinder makes about 30 turns per minute.

Proteaux gives the approximate loss of fibre by sorting, cutting, and dusting as follows: whites, fine and half fine, 6 to 9 per cent.; white, coarse, 10 to 15 per cent.; cottons, white, 6 to 10 per cent.; cottons, colored, 10 to 13 per cent.; pack-cloths and coarse threads containing straw, 15 to 20 per cent.; ropes, not of hemp, 16 to 18 per cent.; hempen ropes containing much straw, 18 to 22 per cent.

Boiling with alkalies is the next step in the cleansing process. Its object is to loosen the dirt, and remove all grease and glutinous and coloring matter, preparatory to washing. The liquor used is a solution of lime, soda-ash, or caustic soda in water. To dissolve 1 lb. of lime requires 1,200 lbs. of water; and for 100 lbs. of rags, 5 to 15 lbs. of lime are used. The best results are obtained by boiling in lime, then in a separate solution of soda. Caustic soda may be required to cleanse some stock. The rags are boiled either in stationary tubs or rotary boilers. Rotary boilers are now generally used. They are horizontal, revolving sheet-iron cylinders, with cast-iron heads. The sizes range from 12 to 25 ft. in length, and from 5 to 8 ft. in diameter. Steam at a pressure of from 20 to 60 lbs. is used. The liquor is poured in after the rags, and must cover the openings for steam, that the latter may not impinge directly upon the rags, but be forced through the liquid. A boiler 6 ft. in diameter and 16 ft. long holds from 3,500 to 4,000 lbs. of rags.

8356.

Washing is effected by rubbing the rags in water in a *washing engine*, or *Hollander* (Figs. 8356 and 8357), as it is sometimes called from the country where it was first used. It is an oblong vessel with semicircular ends. The sizes vary from 12 to 24 ft. in length, 5 to 8 ft. in breadth, and 2 to 3 ft. in depth, and hold from 100 to 1,500 lbs. of rags. A medium-sized vat, to hold 400 to 450 lbs. of rags, would be about $15 \times 6\frac{1}{2} \times 2\frac{1}{2}$ ft. A vertical partition called a *midfeather*, of equal height with the sides of the vat, and of equal length with the straight portion of those sides, divides it longitudinally through the middle. A shaft, *d g*, extends transversely across the vat and bears a wooden roll *a*, which revolves in one of the spaces between the midfeather and the side. The roll carries a number of bars or blades called *roll-bars* or *fly-bars*. These are of iron one-half to five-eighths of an inch thick, edged with steel. They are placed $2\frac{1}{2}$ or 3 in. apart, parallel with each other and with the roll-shaft. Beneath the roll is a bed-plate, *b*, which also contains knives similar to those of the roll, but bent to present an angle to the latter. Zigzag plates of thin steel are sometimes used for bed-knives. The fly-bars project beyond the face of the roll, and thus form buckets, which gather the rags to themselves and drag them over the bed-knives, thus subjecting them to a rubbing operation. The bed-plate is placed a few inches above the bottom of the vat, and on the approach side has an incline leading up to it, wherein is placed a sand-trap, in which the heavy substances will collect and thus be prevented from passing beneath the roll. On the opposite side of the roll the bottom curves upward, following the sweep of the fly-bars, and forms a breast to the roll. The descent *h*, down which the rags drop after passing over the top of the breasting, is called the *back-fall*. Washing cylinders, *c*, are placed in the vat at the opposite side from the roll. They are cylindrical or eight-sided frames covered with fine wire cloth, through which the wash-water strains to the interior of the cylinder, which is formed into buckets, which gather and discharge it over the side of the vat. A siphon pipe is sometimes used within the wash-cylinder instead of buckets, but it is not so reliable. A continual supply of filtered water enters by the pipe *w*, the end of which is often covered by a flannel bag which serves as a strainer. The water used in all the processes of paper-making must be the purest that can be obtained. The washing is accomplished in 3 to 5 hours.

8357.

Half-Stuff.—The washing of rags and their reduction to pulp are, for coarse paper, sometimes effected in the same engine. For the fine papers the reduction in the washing engine is but partial. As soon as the rags are washed, the roll is lowered, causing them to be severely rubbed as they pass the knives, and the roll is gradually lowered as the rags become more completely separated into threads and fibres. It is essential that the pulp should be even; therefore it is kept well stirred up by paddles, or mechanical propellers, to produce increased rapidity of circulation. Different kinds and qualities of stock require different treatment to reduce to the same degree of fineness, and are therefore beaten separately. *Bleaching* is almost universally effected by the addition of a solution of the ordinary bleaching powders of commerce to the half-stuff in the washing engine. The quantity of commercial powders is from 4 to 10 lbs. for each 100 lbs. of rags, according to their quality. Vitriol is sometimes added to facilitate the action of the powders. After the bleach-solutions are thoroughly incorporated with the half-stuff, a valve in the bottom of the engine is opened, and its

contents flow through a pipe into the drainers—vats which hold the pulp until it is needed to furnish the beating engine. The water is immediately drained off, as the solutions are strong, particularly if much vitriol has been used. The half-stuff is washed thoroughly in the washing engine. Chemicals are added to facilitate the cleansing action. "Antichlor," which is largely used, is a compound of sulphate of soda, chloride of tin, and hyposulphite of soda. Sulphite of calcium is also used.

The Beating Engine receives the half-stuff from the drainer-vats, and separates it into its ultimate fibres, which with water form the pulp. The one most generally used resembles in every essential the washing engine. It runs a little faster, and the knives used are not so blunt. The treatment the pulp receives varies greatly according to its quality and that of the paper which is to be made from it. For coarse paper the stock is often beaten in 5 or 6 hours; good writing paper is generally beaten 10 or 12 hours; and in cases where the greatest attention must be directed toward obtaining great length and strength of fibre, as for bank-note and bond papers, the stuff is "brushed;" that is, the fly-bars barely touch, and the pulp is merely rubbed under comparatively light pressure from 24 to 72 hours. *The Jordan & Eustace engine* consists of a revolving cast-iron core inclosed in a cast-iron conical casing. Both cone and covering are furnished with steel knives. The pulp, diluted with water, is fed into the engine through a regulating box at the smaller end, and is forced forward by centrifugal action and beaten or rubbed between the knives in its passage, and delivered perfectly reduced at the larger end. The cone makes from 200 to 300 revolutions per minute. *The Kingsland pulping engine* has a revolving cast-iron disk 30 in. in diameter, with steel knives on both faces. It turns in a cylindrical chamber, whose faces adjacent to the disk are also provided with steel knives. The pulp is fed into the chamber at the centre of one side, passes outward between disk and chamber walls, around the periphery of the revolving plate to its other side, and out at the centre of that side.

Dyeing and Coloring is effected by adding the ordinary colors used for dyes and paints to the pulp in the beating engine.

Size is added either to the pulp in the engine or to the surface of the paper when formed, or both, according to the character of the stock used and the paper to be made from it. The objects of sizing are to add to the weight or strength of paper; to fill the pores so that ink may not spread; and to give a good working surface, or a surface which can be well finished. Print papers require little or no sizing, as printing inks do not spread. *Vegetable size* is used in the engine. It is made of resin dissolved in a solution in water of ordinary soda-ash or crystals of soda, in proportion ranging from 2 to 5 lbs. of resin to each pound of soda. The compound when assimilated resembles soft soap. Other substances are added for different purposes, notably clay, China clay, and kaolin, to give weight to the paper; also starch, gum tragacanth, and alum. The last brightens many colors.

Stuff-Chests.—The pulp leaves the beating engine, and is drawn off into stuff-chests, which are vats large enough to hold the contents of several engines. They are circular, and contain agitators which keep the pulp in continual circulation, and therefore in a uniform condition of fluidity. The pulp in the stuff-chests is too thick to be used in the paper machine. It is therefore, as it is needed, pumped into a mixing box, and there diluted with water to the amount suitable for the desired weight and size of paper.

Paper-making by Hand.—The pulp is properly diluted in a vat. The workman is provided with a *mould*, which is a frame across which is stretched a wire cloth, the whole forming a kind of sieve. Upon this is placed an open frame called a *deckle*, which is of the size of the intended sheet, and confines the pulp to the space upon the mould which is inclosed by its sides. The proper quantity of pulp is dipped from the vat by the mould. The workman holds the latter with its contents in a horizontal position, and, while the water is draining through the bottom, gives it a peculiar shaking motion which causes the fibres to intertwine or felt. When the pulp is deposited, the vatman removes the deckles, and slides the mould along the vat to another man, called the *coucher*. The latter sets it upon edge to drain, while he lays upon the table at his side a sheet of felt, upon which the fibrous sheet is then laid by carefully overturning the mould. The mould is returned to the vatman, who immediately pushes forward another sheet, which is laid upon a sheet of felt placed upon the preceding sheet of fibre. A pile of five or six quires, each of alternate layers of paper and felt, is thus formed. This pile is pressed to squeeze out the water and to give firmness of texture to the paper sheets. The latter are separated from the felt and again pressed by themselves, and likewise a third time. The sheets are dried in lofts, as will be subsequently described, after which they are sized by being dipped in a solution of glue and alum. They are again pressed, and slowly dried. The papers are finished by being placed in alternate layers with glazed card-board, and pressed. The sheets are thus cold-pressed. When hot plates are interspersed throughout the pile, the sheets are said to be hot-pressed. Bond and bank-note papers are to a limited extent made by hand, as are also the finest drawing-papers. A sheet of "antiquarian" drawing-paper, which measures 31 x 52 in., requires eight or nine men to manipulate it.

Paper-making by Machinery.—The finest papers are made upon the *Fourdrinier machine*, Fig. 3358. The pulp, properly thinned in the mixing box, is pumped into a regulating box, from which it passes beneath a copper gate whose height governs the quantity which may be used. A surplus of pulp is always delivered to the regulating box. That which is not needed passes out by an overflow, and returns again through the pump. A continuous circulation is thus kept up. The same water is used over and over, only sufficient being added to compensate for that which fails to drain from the pulp. Fan-pumps are used, as they also serve as agitators to keep the pulp well stirred. The pulp flows from the regulating box into a *sand-table* (sometimes omitted), which is a shallow box traversed by low partitions over which the pulp flows, leaving the heavy impurities to collect on the bottom between them. Clots of fibre which have lodged in some corner of the beating engine, and escaped reduction, are caught by strainers, screeners, or pulp-dressers, *b*, as they are variously called, which are generally formed of brass plates with narrow slits, whose gauge determines the fineness of the pulp. The width of the slit is greater at the bottom than at the top, to give a ready clearance to the

pulp in passing through. The plates are supported by a frame whose sides dip into a vat containing pulp, which seals it from the air except such as enters through the slits. A suction-box is thus formed, to which a vertical motion is given by tappets. The upward lift causes a partial vacuum, which draws the fibre through into the vat. When the stuff is found to be so "free" that it will part with its water rapidly enough to leave the fibres themselves upon the plate, the level of fluid in the vat is brought up to the under side of the plate. Another kind of suction screener, occasionally seen, has plates against the lower face of which a plate faced with rubber alternately presses and is withdrawn. Brushing off the deposit from the surface of the screen-plates causes some of the screenings to pass through, and they subsequently show as imperfections in the paper. This is avoided in the *Ibbotson strainer* by the use of two screen-plates. The pulp which flows through the first, flows at once to the wire upon which the paper is formed; the remainder, flowing over the surface of the first plate, passes to and through the second screen-plate, leaving the screenings on its surface, from which they are then removed. The pulp from the second screen-plate is diluted and pumped back to the first plate. *Reversed screens*, in which the pulp passes upward from below, are sometimes used to supplement the ordinary kind. After passing through the screen-plates the pulp flows into a box *a*, containing an agitator *c*, an outlet gate, and an overflow for the pulp in case the box should be filled before time has been given to shut off the flow of pulp. The gate is adjustable to the quantity of pulp required for the weight of paper to be made. The pulp passes through the gate on to an apron of leather, rubber-cloth, or oil-cloth, whose sides are turned up to give a width of flow suitable to the width of paper being made. In another form the sides are of wood, and can be made to approach or recede from the centre by means of right- and left-handed screws. The pulp flows from the apron on to an endless wire cloth *d*, upon which the paper is formed. The water strains through, leaving the pulp as a thin sheet upon its surface. The wire is supported in a perfectly horizontal plane by means of numerous tube-rolls placed so closely as almost to touch each other. At either side of the wire cloth an endless rubber band, *e*, about 1¼ in. square, bears upon and is moved by it. These are called *deckles*. They are made heavy that they may bear closely upon the surface of the wire and prevent any pulp from passing beneath them. The pulp is therefore confined to the space between them, and this space or width is adjusted to determine the width of paper, which at this point is enough wider than the finished paper to allow for shrinkage and trimming. The horizontal or working face of the wire roll extends from the *breast-roll*, which is beneath the apron, to the *couch-rolls*, which remove the paper from the wire cloth, a distance of about 15 ft. The wire, deckles, and rolls, except the couch-rolls, are supported in a frame to which a vibratory or shaking motion is given. The frame is pivoted near the couch-rolls, and motion is given by a crank or cam near the apron. The motion is therefore the greatest where the pulp is most fluid, and diminishes as the web or sheet becomes free from water. The object of the shaking motion is to intertwine or felt the fibres; without it the tendency would be for the fibres to be laid in one direction, that of the length of the paper. The water which does not drain naturally from the pulp while on the wire is removed by two suction-boxes *h*. The tops of the boxes are upon a level with the wire cloth, and at that point support it. They are of brass, rubber, or glass, and are perforated with numerous holes. Within the boxes are sliding partitions; the distance between the partitions is made equal to the width of the paper passing between them. The space outside the partitions at the ends of the boxes, not covered by the paper, is filled with water. The boxes are therefore practically air-tight, being sealed by the water at the ends and covered with the paper at the top. The air is exhausted from the interior of the boxes by means of a pump or by a siphon pipe, and atmospheric pressure forces out the water from the paper as it is dragged over it. A box called a *save-all* extends beneath the wire from the breast-roll nearly to the suction-box, and receives all the water which drains from the pulp. This water supplies the mixing box above mentioned. It is appropriately named, as it saves fibres, coloring matter, and size, which otherwise would be lost. Letters, figures, and various designs are impressed upon this paper by a *dandy-roll* or *fancy-roll*, which is a wire cylinder placed between the two suction-boxes, and made to revolve by contact with the paper, or *web* as it is now called. The designs are formed by wires in relief which indent the paper. If the wire used is very fine and without projecting wires, the paper is said to be *wove*. If it has parallel wires which form lines upon

the paper, the latter is called *laid*. The various designs formerly used gave names to the paper to which they were applied, some of which are still retained. A fool's cap and bells gave the name of "cap" or "foolscap;" a postman's horn, "post" paper; a hand, "hand" paper; a pot or jug, "pot" paper, etc. After passing the suction-boxes the paper or web passes between two couch-rolls *i*, *i*, to the upper of which it goes, leaving the wire cloth which passes downward and backward beneath the save-all on its return motion. The web is delivered from the couch-roll to an endless apron or felt *k*, by which it is carried between a pair of cast-iron press-rolls *l*, *l*, 12 to 18 in. in diameter, which squeeze out the water. As the lower surface of the paper presses upon the felt, the paper is passed to a second felt, which with a reversed motion carries it through a second pair of press-rolls *n n*, to give both surfaces the same treatment. The first is called the *wet felt*, the second is called the *press-felt*. The wet felt becomes loaded with size, etc., after a while. It is cleaned by passing through a trough of water and then being subjected to beating by revolving blades. The press-felt is removed from the machine and cleansed by hand or by running it through a washing machine. The paper is now nearly freed from water, and what remains is evaporated by passing the web over driers, 1, 2, 3, 4, 5, 6, 7, 8, which are cast-iron hollow cylinders 30 to 40 in. in diameter, heated by steam which enters through their journals. The condensed steam is removed by pipes which lead outward through one of the journals. The temperature of the driers is adjusted to the requirements of the paper, and the latter is dried slowly and with a gradually increasing temperature. The paper is supported and pressed against the cylinders by drier-felts, which, outside of the paper, wrap about the cylinders. From the driers, the paper, if *engine-sized*, is passed through the calenders (see CALENDER), which are a number of chilled cast-iron rolls, accurately ground and with polished surfaces, placed in a stack, that is, vertically one above another. The paper in passing through is subjected to great pressure, which gives it a dense, smooth surface. The surface of the paper when it leaves the driers is somewhat hard, and does not readily take the impression of the calenders. It is therefore in some machines moistened slightly by a steam-jet. The latter serves also a useful purpose in drawing off the electricity with which the paper becomes charged in passing over the driers. The action of the calender also charges the paper with electricity, and this is sometimes drawn off by passing over a copper roll with a wire connecting with the soil or some good conductor. It is important that the electricity should be removed, as its presence causes the sheets to stick together so that it is difficult to separate them. *Surface-sizing*, if required, is next effected by leading the paper through troughs containing animal size or glue. The paper then passes on its way to the cutters over rolls, which keep it stretched and prevent wrinkling.

The paper itself is now finished. It is delivered to and wound upon reels *r*, in readiness to be trimmed at the edges and to be cut into sheets. It is divided lengthwise by *slitters*, which consist of two parallel horizontal shafts, each bearing a number of cutting disks, the distances between whose cutting edges are set to correspond with one of the dimensions of the sheets into which the web is to be divided. These narrower bands are divided transversely by *stop-cutters* or *continuous cutters*.

Stop-Cutters.—In these the sheet is fed forward the proper distance, and then stops while the cut is being made. They have either two straight cutting blades set at right angles to give a draw-cut, as in Coffin's cutter, or a horizontal straight-edged bed-knife and a revolving cutting blade, which winds about one-fourth of the circumference of the roll which bears it. The bed-knife of the last-named machine is hinged and backed by a spring to permit the slight yield made necessary by inequalities in the edge of the revolving blade, while keeping the cutting edges of the knives in working contact. When the feed-rolls stop to permit cutting, the roll continues to unwind, forming a loop which is carried downward by the weight of rolls. When the sheet is again fed forward for another cut, the tension upon the paper lifts the rolls.

Continuous Cutters.—In Gavitt's cutter the paper is fed vertically downward in front of a straight-edged bed-knife, which inclines from the horizontal an amount which, in the width of the web being cut, is just equal to the distance which the paper travels while being cut. The movable cutter is a spiral blade which begins to cut at the higher end of the bed-knife, and the cutting points traverse the blade to its lower end with the same rapidity that the paper itself moves downward, thus keeping the same horizontal line relatively to the paper itself. One sheet is cut at each revolution of the spiral blade. The speed of the feed-rolls is constant, the length of the sheet being determined by the frequency of revolution of the spiral blade. Both cutting blades are supported in the same bed, that they may always keep the same relative positions. The inclination of the knives to the paper is adjusted to each size of sheet. The Fletcher cutter has a plate attached to the bed-knife at the point where the cut commences; the edges of the cut coincide, but beyond this point the plate overhangs the blade to a gradually increasing extent. The paper must bend around this plate before it can be cut, and in so doing the line in which the cut is made is drawn up to the same extent that it is fed forward, and is therefore made square across the paper.

The sheets as they are delivered by the cutter are received by attendants, one for each train of sheets, and the defective ones thrown aside. For the finer papers which are quite uniform in quality, the *Kneeland layboy* is used. The sheets as they drop from the cutter are struck from behind at some distance from their edge by a roll over which they fold, and are thus carried forward by the roll. Suspended from a rod above are a number of strips of felt, which rest upon the upper fold and hold it in place. The lower fold is supported by wooden slats until the sheet reaches the place where it is to be deposited, when it drops from the slats on to boards placed to receive it, or upon sheets previously laid. At that moment the carrier-roll begins to revolve in the direction of its forward motion, and with equal speed of motion, so that the upper fold is drawn forward and laid in position. The boards which support the sheet rest upon a platform which is carried by vertical screws at the sides, which are turned by gears and ratchets so adjusted to the thickness of the sheets that the platform descends with the same velocity as the depth of the pile increases, and thus keep the top of the pile upon the same level. When the depth of the pile has become as great as is desir-

able, the supporting boards reach the top of a truck beneath, by which its weight is borne and by which it is rolled away from the machine and the paper removed and carried to the finisher, whose work will be noticed below.

After the paper has been cut into sheets, it is carried to *drying lofts*, where the moisture not removed by the driers and that added by the size is slowly evaporated. Paper dried in the web or roll is passed over rolls beneath which are steam-pipes for heating, and revolving fans for rapid circulation of air.

Cylinder Paper Machine, Fig. 3359.—The pulp, after passing through the strainer, flows into a vat with a semi-cylindrical bottom. In this vat revolves a cylinder covered with a wire cloth. One end of the cylinder is closed; the other end has an opening about the shaft, out of which flows water drained from the pulp. The pressure of the fluid within the tank forces the pulp against the wire cloth. The water passes through to the interior of the cylinder, and the pulp remains pressed against the wire cloth. The cylinder revolves, carrying upward the pulp attached to it, which forms a web upon the cylindrical surface, and is removed as a continuous sheet by a roll which presses the cylinder at its highest part. The water which flows out from the cylinder passes into a box, from which it is pumped into a trough with a perforated bottom placed over the vat, into which latter it drains and again unites with the pulp. The paper-making cylinder itself serves instead of a lower couch-roll. The upper roll, or couch-roll proper, is of wood, 12 to 18 in. in diameter, and is covered with several thicknesses of felt. It is weighted to press out the water from the pulp. This roll forms one of a number which carry the wet felt and the paper which adheres to it through the press-rolls, then through the second press-rolls to cylindrical driers, as in the Fourdrinier machine. The shaking motion which felts or intertwines the fibres upon the Fourdrinier machine is wanting in the cylinder machine, so that fibres tend to lay themselves upon the cylinder in a direction parallel to its line of motion, causing in the completed paper a grain in the direction of its length, which permits it to be much more easily torn in that direction than across the paper. This defect is in a slight degree remedied in some machines by the use of agitators which revolve in the

vat close to the cylinder. As the fibres are laid upon the cylinder merely by the side flow and pressure of the water, this machine cannot make thick paper of an even texture. Where the latter is desired, two or more cylinders are used. The webs from each are laid upon one wet felt, and, passing through the press-rolls together, are pressed into one web. As many as six cylinders have been combined in one machine for the manufacture of heavy boards. The number of drying cylinders is increased in proportion to the thickness of the paper; as many as 20 are sometimes used with a single machine. Machines with two cylinders and two vats, each with a different pulp, are used for the production of paper having its two surfaces of different textures or colors. The first cost of the cylinder machine is much less than that of the Fourdrinier. It occupies less space, is more easily managed, and costs less to run. Much news- and book-paper, and nearly all coarse wrapping paper, are made upon cylinder machines.

The Harper Paper Machine is a combination of the Fourdrinier and cylinder machines. The pulp receives the same treatment as in the Fourdrinier machine until the web is formed. It is removed from the wire cloth by the lower couch-roll, which is a paper-forming cylinder. The latter delivers the web to the same wet felt which passes around the upper couch-roll, and carries the paper through the first press and up to the second press. Any thickness of paper can be made with this machine.

The Scanlan Paper Machine makes a two-web paper. One web is formed upon a Fourdrinier wire cloth and the other upon a cylinder. The two are united by pressure between rolls. The two sides of the paper thus formed can be of different textures and colors.

The Harris Paper Machine has two forming cylinders placed in one vat. The agitators are placed vertically at the ends of the vat.

Paper-making from Materials other than Rags.—*Waste paper* ranks next in importance to rags. It is in fact only pulp which merely needs reworking. The very highest grade is composed of cuttings from fine white papers, and is called *white shavings*. These are subdivided into *hard* or *sized* and *soft* or *unsized shavings*. Colored shavings are the cuttings of colored papers. Old blank books and letters, and other papers which contain writing ink, are excellent. Printed papers are divided as follows: *No.* 1 *imperfections* contain best qualities of clean printed papers, such as books whose bindings have been removed, blank books, and letters with printed headings, and other good papers which contain but little printer's ink. *No.* 2 *imperfections*, or *No.* 1 *prints*, are the waste of white printed papers and clean newspapers and pamphlets. *No.* 2 *prints* are made up of soiled printed or writing papers which were once white. Manilla papers, straw papers, wrapping papers, straw boards, etc., are put up separately.

Straw Paper, unbleached.—The full-length straw is laid in large stationary wooden boiling vats. A solution of lime in water is poured over it, and the mass boiled several hours. The liquor is then drained off, and water is added to wash off the lime which may adhere to the straw. The latter is then washed in the washing engine, beaten to pulp, and emptied into stuff-chests ready for the machines. Cylinder paper machines are used.

White Straw Paper.—The straw is cut into short lengths and fed to a cleaning machine, which frees it from grain, chaff, and dirt. It is then boiled in a rotary boiler with soda made caustic by lime. The straw is emptied from the boiler into a vat beneath, which serves either as a drainer or for washing the straw. The bottom is perforated and covered with coarse matting or bagging. If the straw is washed in the vat, the water enters at the bottom and works upward through the mass. Any bits of straw which have escaped reduction are skimmed off. The use of the washing engine is preferable. The pulp is pumped into it from the receiving vat. The engine has a smooth bed-plate and blunt knives. The pulp is emptied from the beating engine into a drainer, when it receives the same treatment as rag pulp. It is finally made into paper on a cylinder machine.

Esparto Grass, a spontaneous growth of the gravelly and sandy soil of eastern Spain and northern Africa, is treated in a similar manner to straw, but makes superior paper, as its fibres are tougher. It may be made into paper either on a cylinder or a Fourdrinier machine.

Wood Paper.—The wood used is chiefly American poplar or whitewood, in the form of cord-wood 5 ft. long. It is cut into slices about half an inch thick across the grain, being fed to a rotary disk armed with strong knives. The chips are placed in upright cylindrical boilers about 5 ft. in diameter and 16 ft. high, with hemispherical ends, and provided inside with perforated diaphragms, each space holding a quantity of chips equal to a cord of wood. A solution of caustic soda is then introduced, and fires are started underneath. The digestion is complete in about six hours, when the contents are suddenly emptied with violence, under a pressure of 65 lbs. to the square inch, into a sheet-iron cylinder at the side of the boiler. It now being in the condition of half-stuff, it is passed through a bleaching engine and mingled with rag pulp in the beating engine, in the proportion of from 60 to 80 per cent. It is then formed into paper in the same way as pure rag pulp.

Cane.—The cane which is principally used grows in the Dismal Swamp and along the rivers of North and South Carolina. It is about 12 ft. high, nearly white, and composed of tough strong fibres. The cane is disintegrated by the Lyman process. Strong cast-iron cylinders 22 ft. long and 12 in. inside diameter, having strong heads at both ends, are laid horizontally on heavy frames. Each cylinder has a dome on top to give steam-room. The cane, after having been stripped and cleaned, is introduced into both ends, and the covers are fastened, when steam is admitted into the cylinders or "guns," as they are called, until a pressure of 180 lbs. to the square inch is reached. This pressure is maintained for about 12 minutes, when by pulling a trigger the covers are suddenly unfastened, and the steam rushes out with a tremendous explosion, carrying the disintegrated cane before it. A target placed about 30 ft. from the gun receives the charge, which is reduced to a mass of brown sugary-smelling fibre. The gun holds about 100 lbs., and is loaded and discharged every 15 minutes. The fibre in this condition is shipped for use in wrapping and roofing papers, boards, etc. If further treatment is desired, the fibres, after their discharge from the gun, are thrown into large tubs, from whence, by currents of water discharged from a pump, they are carried beneath four rolls similar to

those of a beating engine, which are arranged in one line, so that the fibre passes from one to another. It is by these washed and beaten, and from the last roll is delivered upon an endless wire apron, which carries it through several sets of iron rolls, of which the last is covered with India-rubber. These rolls squeeze out the water from the fibre and reduce its bulk about one-third. The fibre is then dried. Afterward it is fed to a picker, which delivers it evenly upon an endless apron, which slowly carries it through a long drying house, delivering it at the farther end perfectly dry and ready to be boiled for shipment. The pulp makes good paper, either alone or mixed with harder stock.

PARTICULAR KINDS OF PAPER.—*Bank-note Paper* is made from the most carefully selected white linen or flax threads. The stock is boiled in wooden tubs and washed in the engine. Very little bleaching powder is used, and no vitriol. It is beaten with extreme care, that the fibre may not be broken. Brass bed-plates are often used, and the stock is lightly brushed from 48 to 72 hours. A small quantity of rosin soap is added to slightly size it. It then goes to the Fourdrinier machine, and is treated like letter-paper. The dandy puts on the necessary water-marks. The paper is animal (surface) sized, cut into sheets, and dried in lofts or over steam-driers. These papers do not require a smooth surface, and it is necessary to preserve water-marks; therefore they are not super-calendered. The sheets receive a "dead finish" by being laid between pasteboards, the sheets and boards alternating, and the pile subjected to great pressure. The red silk fibres seen in the U. S. Government notes are mixed with the pulp in the engine. The paper-machine has no screen, as this would remove the silk. Above the wire cloth is an arrangement for dropping upon the pulp the blue threads seen upon the face of the notes. A considerable quantity of paper for bonds and notes is hand-made. It is considered stronger, and when the character of the water-marks is of much importance is by some preferred, as the proportions of the designs are more perfectly preserved than when made upon a machine, where it shrinks uneqally.

Tissue Paper, because of its thinness, requires long and strong fibres. It is made as other rag-papers, and is colored in the engine. It requires to be carefully supported in its course through the machine. The first and second presses are placed near each other, and the web passes immediately from one through the other. Between the press-roll and the driers it is supported by a wooden roll. When the web is first formed, a sheet of dry paper is laid upon the pulp, pressed into it, and dried with it. This sheet leads the way through the several parts of the machine, as the tissue paper itself is too thin to bear handling. Copper drying cylinders are used, as the paper would stick to iron ones.

Collar Paper is composed of cotton rags with a small proportion of linen. It is beaten lightly for a considerable time to obtain a pulp of the requisite sponginess and strength. Cylinder machines with two or three forming cylinders are used. Some cylinder machines have an endless wire cloth placed around but not touching the upper roll of the first press, except where it presses the paper. The paper passes between it and the felt which covers the lower roll. This wire cloth allows the water to escape through it from the upper roll. Cloth lining is either pasted upon the paper by the collar-manufacturer, or enters the press-rolls with the pulp and thus forms a part of the web itself.

Straw Boards.—The straw is treated as described for straw paper. The boards are formed either upon a Fourdrinier machine or upon a cylinder machine having, according to the thickness of the board, two to six forming cylinders. The first press has two wet felts, that the water may be removed from the upper as well as the lower side. When the boards are to be lined with paper, a trough containing paste is attached to the machine, and the paste is transferred from it to the paper used for lining. The latter unwinds from a reel, and passes with the board to the drier-cylinders.

Binders' Boards are made of the cheapest stocks—anything which will make them hard and stiff. Rope or bagging is generally used as hard stock. Usually, the stock is not even boiled, but is put directly into the engine, beaten, and then emptied into the stuff-chests. The boards are formed upon a simple kind of cylinder machine. The upper press-roll is of wood, and its circumference is made equal to the length of one or two boards. The paper from the forming cylinder winds about this roll until a sufficient thickness has been obtained. It is then cut through by a knife, guided by a groove cut in the roll. The sheets are flattened out, and piled up with sheets of felt—one to every two or more boards, according to their thickness—and pressed. They are then partially dried by heaters, and as soon as they become stiff enough to handle are carried out of doors in pleasant weather, or, if the atmosphere is humid, to drying-rooms where they are hung up by a corner. Preparatory to calendering, their surfaces are moistened by placing them in close boxes within which steam is admitted. They are then run through calender-rolls.

Building Paper is made mostly of woolen rags, with which is mixed sufficient hard stock to give the necessary strength. Woolen rags are used because a porous stock is required to absorb and hold the coal-tar. Blown cane-fibre makes good stock.

Building Boards are made of the cheapest materials, and are mixed with different substances to render them waterproof and fireproof. They are made either upon Fourdrinier or cylinder machines.

Leather Boards.—Leather clippings, cut into small pieces and mingled with an equal quantity of waste paper and bagging, are mixed, washed, and ground in the engine. The pulp is made into boards upon cylinder machines. No sizing is required, as a sufficient quantity is contained in the leather itself. The boards are very hard, resembling leather, and possessing many of its qualities.

Parchment Paper is made of unsized paper. It is dipped into or passed through a bath composed of two volumes of sulphuric acid to one volume of hot water. The paper thus treated becomes very strong, waterproof, and translucent, and resembles very closely animal parchment. A bath of alum succeeded by one of concentrated sulphuric acid is claimed to make paper very strong without diminishing to any great extent its pliability and opacity.

Sponge Paper is made by adding finely divided sponge to ordinary pulp. The paper made from this mixture absorbs moisture readily, and retains it. It is used in surgery, and has many other technical applications.

The *carbolic-acid paper* used for packing food is prepared by melting 5 parts of stearine at a gentle

heat, and then stirring in thoroughly 2 parts of carbolic acid, adding 5 parts of melted paraffine. The whole is well stirred until it cools, after which it is melted and applied with a brush to the paper.

An *incombustible paper* is made of vegetable fibre 1 part, asbestos 2 parts, borax one-tenth part, alum one-fifth part.

Tracing Paper is made from tissue-paper of even texture, which is treated with oil and solutions of resins or varnishes.

NAMES AND SIZES OF PAPERS.—*Writing papers*—foolscap, 13½ × 17 in.; small post, 15¼ × 19; large post, 16½ × 20¾; demy, 15½ × 20; medium, 17½ × 22; royal, 19 × 24; super-royal, 19 × 27. *Printing papers*—demy, 17½ × 22½; medium, 19 × 24; royal, 20 × 25; super-royal, 20½ × 27½; imperial, 22 × 30. *Writing papers for printing*—double foolscap, 17 × 27; double crown, 20 × 30; double post, 20 × 32. *Drawing papers*—cap, 13 × 16; demy, 15½ × 18½; medium, 18 × 22; royal, 19 × 24; super-royal, 19 × 27; imperial, 21½ × 29; elephant, 22¾ × 27¾; Columbia, 23 × 33¾; atlas, 26 × 33; theorem, 28 × 34; double elephant, 26 × 40; antiquarian, 31 × 52; emperor, 40 × 60; also in rolls of 10 to 150 lbs., and 40, 44, 48, 50, 54, 58, and 60 in. wide. *Tracing papers*—double crown, 20 × 30; double double crown, 30 × 40; double double double crown, 40 × 60. *French vegetable*—grand raisin (or royal), 18 × 24; grand aigle, 27 × 40. Tracing paper is also made in rolls of about 42 in. in width.

A *quire* is 24 sheets; a *ream*, 20 quires; a *bundle*, 2 reams. A *sheet* folded once forms 2 leaves or 4 pages, and is then called a folio; if the latter be folded, the sheet forms 4 leaves or 8 pages, and is called *quarto*, or, abbreviated, *4to*; a 12-leaved sheet is called *duodecimo*, or 12*mo*; one of 16 leaves, *sextodecimo*, or 16*mo*; 18 leaves, *octodecimo*, or 18*mo*; 24 leaves, *vigesimo-quarto*, or 24*mo*; 32 leaves, *trigesimo-secundo*, or 32*mo*; 48 leaves, *quadrigesimo-octo* or 48*mo*; 64 leaves, *sexagesimo-quarto*, or 64*mo*.

Works for Reference.—"British Patents abridged—Manufacture of Paper, Pasteboard, and Papier Maché;" "Paper and Paper-making, Ancient and Modern," Herring, 3d edition, London, 1863; "A Practical Treatise on the Manufacture of Paper in all its Branches," Hoffmann, Philadelphia, 1873; "A Chronology of Paper and Paper-making," Munsell, 4th edition, Albany, 1870; "Practical Guide for the Manufacture of Paper and Boards," Proteaux and Lenormand, translated by Horatio Paine, Philadelphia, 1866; "Bamboo considered as a Paper-making Material," Rutledge, London; "Die Tapeten- und Buntpapierindustrie," Exner, Weimar, 1868; "Praktisches Handbuch der Papierfabrikation," Hoffmann, 1875; "Handbuch der gesammten Papierfabrikation, nebst Bemerkungen über die Anlage und Verwaltung der Papierfabriken," Lenormand, Weimar, 1862; "Die Fabrikation des Papiers," Müller, Berlin, 1862; "Fabricant de Papiers Carton et Art du Formuaire," Lenormand, Paris; "Fabrication du Papier succédané des Chiffons," Payen; "Manuel du Directeur, du Contre-Maître, et des Chefs d'Ateliers de Papeterie, contenant la Description de Moyens Pratiques pour converter le Chiffon et diverses Plantes en Papier," Piette; "De l'Industrie du Papier," Planche. See also the following periodicals: *Paper-Maker's Monthly*, New York; *Paper Trade Journal*, New York; *Paper Trade Report*.

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and are chiefly used for dividing a few sheets into numerous strips at one operation, or to cut several strips in succession.

In the first class of apparatus, the difference between various makes of machines lies in the gearing which transmits motion to the knife. The object sought is to give an exceedingly powerful shearing cut, and then raise the knife by a quick return motion. In order to hold the paper while being cut, clamps are provided, and these in large machines are generally automatic in their action, grasping the paper just before and releasing it just after the stroke.

The simplest form of shearing machine is that represented in Fig 3360. It is merely a pivoted curved blade used for cutting small numbers of cards, which are piled on the table or platform and adjusted by a suitable gauge.

An improved form of power paper-cutter, built by the Howard Iron Works of Buffalo, N. Y., is represented in Fig. 3361. The gearing consists of a crank-wheel, the pin on which enters a slot in a vibrating arm pivoted to a vertical arm, which by a bell-crank connection at *A* causes the raising and lowering of the knife. In rear of the latter the mechanism for moving the self-acting clamp is shown. The knife is leveled and adjusted by the hand-screws shown on the top. This machine is made large enough to cut paper 62 inches in width. In Soule's machine the knife is placed below the bed, and lifts with a shearing cut against a pile of paper held down on the bed by a clamp.

Various arrangements of European machines are described and illustrated in *Engineering*, xix., 44.

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In Figs. 3362 and 3363 are shown examples of machines of the second class. The Franklin paper-cutter, Fig. 3362, manufactured by Messrs. Curtis & Mitchell of Boston, has a presser-bar or clamp *A*, which is brought down upon the paper by the rack and pinion shown. Above this bar slides a carriage which carries a sharp cutting point. The carriage has handles so that the point may be drawn over the paper, thus making the cut. The machine shown in Fig. 3363 serves both for ruling and cutting. The cutting rollers are adjusted on the horizontal shaft in front, and the ruling rollers, which are supplied with ink, are attached by curved arms to a shaft in rear.

PARTITIONS. See CARPENTRY.

PATTERN-MAKING. See MOULDING.

PEDESTALS, or PILLOW-BLOCKS, are bearings for the support of horizontal shafts, generally from beneath. (See JOURNALS.) The approximate weight of the cast iron in pedestals is given by the following equation: $w = 1.1d^3 + 18$ lbs., d being the diameter of the shaft. The following is a

Table of Pedestal Proportions.

Diameter of Journal in in.	Length of Bearing in in.	Height to Centre.	Diameter of Bolts.	Size of Bolt-holes.	Length of Base.	Centres of Cap-bolts.	Centres of Base-bolts.	Thickness of Cap at bottom.
1½	2½	2¼	½	½ × 1	8¼	3½	7½	¼ to 5/16
2	3	2¾	½	⅝ × 1¼	11	4½	9	5/16 to ⅜
2½	3½	3¼	⅝	⅝ × 1½	12½	5½	10½	5/16 to 7/16
3	4	3½	¾	1 × 1½	15½	6½	12½	⅜ to ½
3½	4½	4 1/16	1	1⅛ × 1½	17½	7	14½	⅜ to ½
4	5	4½	1⅛	1¼ × 2	20	7½	15½	7/16 to 9/16
5	6	6	1¼	1⅜ × 2¼	24	9½	19½	½ to ⅝
6	7	7	1½	1⅝ × 2½	28½	11½	23½	9/16 to 11/16
7	8	8½	Two 1⅛	1¼ × 2¼	....	12½	....	⅝ to ¾
8	9	9½	" 1¼	1⅜ × 2½	....	14	....	11/16 to 1
9	10	10½	" 1⅜	1½ × 2¾	...	15½	....	¾ to 1
10	11	11½	" 1½	2 × 2¾	....	17½	....	⅞ to 1¼
12	13	13½	" 2¼	2¼ × 3½	...	21	...	1 to 1½

From 7 in. upward the pedestals have two bolts on each side, both in cap and base-plate.

Pillow-blocks are bolted directly to timbers, or are planed on the bottom and secured to a wall-plate, Fig. 3364, bolted to beams or to a foundation, or often to the under side of girders. They are also frequently bolted to arched wall-boxes built into the walls, or secured to brackets, which may be bolted to a wall or post.

There is some difference of opinion in regard to the metal of which boxes should be composed, especially for very heavy shafts, many engineers still advocating the use of bronze, Babbitt's metal, or some other of the various so-called anti-friction metals. For ordinary service, in situations where access is not extremely difficult, American practice inclines to the use of cast-iron boxes with sufficient lubrication. These are often made (for fast-running shafts) four diameters in length. Fig. 3364 is an example of a pillow-block thus proportioned, made by Messrs. W. Sellers & Co. The steps are supported on the spherical parts, and can rotate slightly either horizontally or vertically. The ordinary lubrication is at the centre of the pedestal. In addition to this, two cup-shaped hollows are formed near the ends of the top step. These are filled with a mixture of tallow and oil, which is solid at ordinary temperatures and melts at about 100° F. If the step heats from failure of the ordinary lubrication, the tallow melts and prevents injury to the shaft. A drip-cup is provided under each end.

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PEDOMETER. An instrument for measuring and counting the steps taken by a person in walking. One of the simplest forms of the instrument is that devised by Mr. Benjamin F. Church, and manufactured by Messrs. Tiffany & Co. of New York, the working parts of which are represented in Figs. 3365 and 3366. The instrument is carried in the pocket like a watch. The recording apparatus is impelled by the oscillations of the weight *A*, which is nearly counterbalanced by the adjustable bowspring. The arm that supports the weight carries the pallets that engage the ratchet-wheel *B* at every oscillation of the weight. The small pinion connected with the ratchet-wheel engages a pair of differential wheels on the back of the dial *C*, one of which is secured to the dial, while the other is placed on a hollow stud, carrying an index-hand in front of a dial. The wheel that carries the index-hand has one tooth less than the other, so that when the dial has been turned through one revolution the wheel that carries the index-hand will have gained a distance of one tooth, recording one revolution to the dial. The instrument may be readily adjusted to any length of step, from 17 to 35 inches, a varying scale on the dial being constructed to admit of this adjustment.

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PEGGING MACHINE. See Shoe-making Machinery.

PENCILS. See Lead Pencils.

PENS. Metallic pens may be divided into two classes, viz.: those which are entirely distinct from the device in which they are held, and which take up only small quantities of ink at a time; and those of a peculiar construction, which are combined with their holders, the latter serving as receptacles or fountains for delivering a continuous supply of ink to the pen-point.

Steel Pens are chiefly made in Birmingham, England, from cast steel produced from Swedish iron. The metal is made into sheets, which are cut into strips of 1¼ to 4½ in. wide. These are roasted in a muffle, cleaned in revolving barrels, and rolled to the requisite tenuity. The pen-blanks are cut out by a press, and the central perforation and side slits are made by dies. Annealing follows, and then raising or bending the blank into curved shape. Tempering in oil and coloring follows. Slitting is accomplished by a descending steel tool.

Gold Pens.—The gold is alloyed with silver and copper, and after being cast into ingots is rolled into thin ribbons. The form is given by dies, and the slit is cut by thin copper disks, which revolve, and are covered with emery-flour and oil. Gold pens are always tipped with iridium in order to prevent abrasion of the points. For a detailed description of the manufacture, see *Scientific American*, xxvii., 178.

Fountain-Pens are of two kinds, those which supply a continuous flow of ink to an ordinary pen, and those which deliver their fluid to a pen of special construction. The number of patents obtained for these devices, especially in England, is very great. In fountain-pens of the first class, the ink is contained in the holder, and is usually carried to the pen by a tube. To force the ink down this tube is the problem. In some cases a flexible bulb is squeezed by the hand of the writer, and in others a piston must be pushed down. None of these pens have come into extended use. The reader interested in them is referred to the patent records of the United States and Great Britain.

Fountain-pens of the second class are of more recent invention, and have proved in some cases

successful. They involve two essential features: 1. An ink-reservoir contained in the handle, through which passes an air-tube open at both ends. The object of this tube is to admit a supply of air into the ink-reservoir so as to compensate for and allow of the escape of the ink. 2. A hollow tip or point, in which reciprocates a needle, said needle being caused to move by its pressure against the paper on one side, and the resilience of a spring on the other; or instead of having a spring, the needle is simply weighted. This needle both forms a valve in the point and at the same time keeps the latter free and clear. The needle-point, valve, and air-tube are essentials, and no pen of this kind has been made which has proved of any value without them.

The Stylographic Pen is represented in Fig. 3367, and is one of the best embodiments of the above-described principles. The air-tube is shown passing through the body of the holder, and to its lower end is attached a spiral spring to which the needle is secured. The reservoir is closed above. The

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air-tube extends up through a projection, and is open at the top. It may be closed by the screw-cap shown. At the bottom of the air-tube is a small orifice for the escape of air. The hollow point or tip is removable, and it is necessary to take it off and invert the pen in order to introduce the ink. In operation, the ink flows down around the needle and out at the point. Its exit is automatically regulated by a partial vacuum which forms above the fluid in the reservoir, only sufficient air entering to compensate for the escape of ink around the needle. The result is that only a very small amount of ink (about one-third of that used in an ordinary pen) is required in writing. The pen works freely and easily, but is not suited for ornate penmanship, as its mark is of uniform width.

The Mackinnon Pen, which antedates the foregoing, is essentially identical with it in construction, except in the needle-valve. The needle is not connected to the air-tube, but is loose, and is surmounted by a leaden weight which takes the place of the spring. This pen also writes well, and is by some preferred to that above described.

PERCUSSION FUSE. See FUSES.

PERROTINE. See CALICO-PRINTING.

PETRISSEUR. See BREAD AND BISCUIT MACHINERY.

PEWTER. See ALLOYS.

PHONOGRAPH. A machine that records sound-vibrations, and subsequently reproduces the same. The term—which in some cases is modified into "phonautograph"—has been more commonly applied to devices which simply record sound-vibrations, usually by sinuous lines on a rotating blackened cylinder. Contrivances of this kind are described in the *Scientific American*, xxxii., 307, 376. Latterly the name has been given by Mr. Thomas A. Edison to a remarkable acoustic invention, which not only records sound, but reproduces the same by mechanical means, and which is therefore both a sound-recorder and a talking machine.

The most perfect example of a talking machine hitherto constructed is that of Professor Faber of Vienna. This inventor worked at the source of articulate sounds, and built up an artificial organ of speech, whose parts as nearly as possible perform the same functions as corresponding organs in our vocal apparatus. A vibratory ivory reed of variable pitch forms its vocal chords. There is an oval cavity whose size and shape can be readily changed by depressing the keys on a key-board. A rubber tongue and lips make the consonants; a little wind-mill turning in its throat rolls the letter *R*, and a tube is attached to its nose when it speaks French. For detailed descriptions, see *Scientific American*, xxvii., 8.

The difference between this machine and Edison's phonograph is summed up by Professor A. M. Mayer (*Popular Science Monthly*, xii., 719) as follows: "Faber solved the problem by reproducing the mechanical *causes* of the vibrations making voice and speech; Edison solved it by obtaining the mechanical *effects* of these vibrations. Faber reproduced the movements of our vocal organs; Edison reproduced the motions which the drum-skin of the ear has when this organ is acted on by the *vibrations* caused by the movements of the vocal organs."

Figs. 3368 and 3369 exhibit the construction of Edison's machine. A cylinder *F* turns on an axle, which passes through the two standards *A* and *B*. On one end of this axle is the crank *D*, on the other the fly-wheel *E*. The portion of this axle to the right of the cylinder has a screw-thread cut on it, which, working in a nut *A*, causes the cylinder to move laterally when the crank is turned. On the surface of the cylinder is scored the same thread as on its axle. At *F* is a plate of iron *A*, Fig. 3369, about a hundredth of an inch thick. This plate can be moved toward or from the cylinder by pushing in or pulling out the lever *H G*, which turns in a horizontal plane around the pin *I*. The under side of this thin iron plate *A* presses

against short pieces of rubber tubing which lie between the plate and a spring attached to E. The end of this spring carries a rounded steel point P, which enters slightly between the threads scored on the cylinder C. The distance of this point P from the cylinder is regulated by a set-screw S, against which abuts the lever $H\ G$. Over the iron plate A is a disk of vulcanite $B\ B$, with a hole in its centre. The under side of this disk nearly touches the plate A. Its upper surface is cut into a shallow funnel-shaped cavity. The cylinder is coated with a sheet of tin foil, against which the point P is brought to bear, so as to make a furrow. The mouth is then placed close to the opening $B\ B$, and words are spoken as the cylinder is rotated with a uniform motion by the crank. The plate A vibrates to the voice, and the point P indents the foil, impressing in it the varying numbers, amplitudes, and durations of these vibrations. If the vibrations given by the voice are those causing simple sounds, and are of a uniform regular character, then similar regular undulating depressions are made in the foil; if irregular, the depressions correspond; and thus the yielding, unelastic foil receives and retains the mechanical impressions of the vibrations. In order to reproduce from these the sound whereby they were made, the plate A with its point P is moved away from the cylinder by the lever $H\ G$. The cylinder is then turned back until the point P is brought opposite the beginning of the series of impressions. The point is then moved close up to the foil, a cone of paper or tin is introduced in the mouth-piece to reënforce the sounds, and the crank is steadily turned. The elevations and depressions which have been made by the point P now pass under this point, and in so doing they cause it and the thin iron plate to make over again the precise vibrations which animated them when they made these impressions under the action of the voice. The consequence is, that the iron plate gives out the vibrations which previously fell upon it, and the original sounds are reproduced.

Numerous accounts of the construction of the phonograph, discussions of its principles, etc., will be found in the files of the *Scientific American*, *Engineering*, *Engineer*, *English Mechanic*, and *Nature*, for 1877, 1878, and 1879.

PHOSPHOR-BRONZE. See Alloys.

PIANOFORTE. A musical instrument, the tones of which are produced by the blows of small hammers upon a series of tightly-stretched elastic steel strings; the hammers being caused through certain connections to rise upon the striking of the corresponding keys of a finger-board, and the tones being strengthened and rendered melodious by the reciprocal vibrations of a sounding-board over or near to which the strings are stretched.

The two largest pianoforte manufactories in the United States are those of Messrs. Steinway & Sons in New York, and Chickering & Sons in Boston. In these establishments every portion of the piano is constructed from the raw material (the first-mentioned firm having a foundry for the casting of its own metal work); and hence they differ from the generality of piano factories, into which many portions of the instrument, such as actions, keys, etc., enter in a finished state. The method of piano-making described in this article is based on the processes of both the above-named manufacturers, the differences between them lying chiefly in the introduction into the instruments of patented devices originated by the respective makers. Messrs. Steinway & Sons, to which firm we are indebted for much information embodied in the following article, possess two factories, one in New York, the other in Astoria, L. I., both of which are worthy of especial note as model industrial establishments. The Astoria buildings comprise a steam saw-mill, iron and brass foundries, and all the plant required for the finishing of frames. Here the construction of the piano begins. The wood, in the form of huge logs, is either floated into a water-basin, or by large band-saw mills it is at once cut up into planks and boards, which, stacked in the open air, form whole streets of lumber. Millions of feet of choice wood are thus kept at hand. For spruce timber, of which sounding-boards are made, the seasoning process is allowed to continue for from seven to eight years, during which time the boards are subjected to repeated examinations and selections, until finally, out of say 100,000 feet of material, scarcely 10,000 feet finds its way into the completed piano. It is hardly necessary, in view of such facts as the foregoing, to point out why pianos that are properly and

carefully constructed are costly to build, or to what qualities they owe their permanence under the influence of the most variable climates in the world. The same critical care is exercised in the production of all the metallic portions of the instrument, and in the foundry skill of no common order is brought to the accurate casting of the iron frames or plates. Some seventy of these are simultaneously cast. Samples of the metal are always subjected to proof-stress in a testing machine. The metal employed contains 3.34 per cent. of carbon as graphite and 1.20 per cent. of silicon, besides manganese and sulphur. This in strength and lightness resembles cast steel, and is found to be especially well suited for its purpose. Special investigations have been made into the method of producing the brass alloys used for screws, action-supports, and bars; and an example of the fineness of the material is shown in the fact that screws made from it are cast with threads apparently as perfect as if cut in the lathe. The Steinway factory in New York city, in which the pianos are put together and their finer portions manufactured, has a surface of 175,140 square feet, and contains 165 machines of various kinds, driven by engines of 380 horse-power. The machinery includes almost every form of wood-working tool in general use, besides numerous special appliances, such as the case-planer, the rim-bending machines, the presses for applying felts to the hammers, etc., which are described further on. Labor is subdivided with great closeness, and each workman is encouraged to devote himself to but one branch of the trade, so as to acquire particular skill in his specialty. The Steinway factories produce some 60 pianos weekly, employ the labor of 1,000 men, and export instruments to all parts of the world.

Designing Pianofortes.—The essential features of all pianofortes are: 1st, the strings by the vibrations of which the musical sounds are produced; 2d, the mechanism for striking these strings, whereby they are thrown into vibration; 3d, the sounding body; and 4th, the case wherein the strings and the striking mechanism are contained.

In designing a piano, the first step is the construction of the scale, by which is meant the preparation of a drawing on which are shown the length and position of every string. This is made either of the full size of the plan of the piano, or on a reduced scale, according to the preference of the designer.

The Construction of the Scale is chiefly dependent upon the laws of physics governing the vibrations of tense strings. Sounds differ from each other in three essential particulars: 1st, in pitch, that is, in gravity or acuteness; 2d, in loudness or intensity; and 3d, in *timbre* or quality of tone. The pitch of the sound always depends upon the number of vibrations communicated to the air in a given time. Rapid vibrations produce sharp, shrill sounds; slower vibrations, those which are more grave. The low C of a piano gives a deep bass note; the highest C, an acute treble one. Not that one of these notes is touched more energetically than the other, but that the string of the former vibrates more slowly than that of the latter. Thus the lowest C of a piano makes only 64 vibrations, while the highest C makes 2,048. A string may be caused to vibrate more slowly by augmenting its length or its weight, or by decreasing its tension. The laws relating to this are briefly as follows:

1. The vibrations of stretched strings are in inverse proportion to their lengths. To lengthen a string, therefore, causes it to vibrate more slowly, and *vice versa*.

2. When strings have the same length and tension, but differ in weight or thickness, their vibrations are in inverse proportion to their weight. If a given string makes a certain number of vibrations in a second, another twice as heavy will under similar circumstances give only half the former number of vibrations in the same time; so that it is evident that if a string is desired to vibrate more slowly, this may be effected either by increasing its length or augmenting its thickness.

3. The third law, which is that the vibrations of a stretched string are in proportion to the square root of its tension, shows that the tighter a string is drawn the faster it vibrates, and the sharper or higher its pitch. On the other hand, the looser the string the slower its vibrations, and the flatter or graver the note which it produces.

While all these laws must be taken into consideration in the construction of the scale, the first two are chiefly regarded by most manufacturers—the third, or the question of the tension of each string, being attended to by the tuner after the piano is completed. The exact tension to which any string has to be subjected to produce a given note has been determined by experiment by Mr. Theodore Steinway, as will be explained further on.

In laying out his scale the manufacturer must consider—1st, the length of his strings; 2d, their thickness; 3d, their arrangement, so as to suit the size and form of the instrument which he proposes to build. In regard to the last, it is obviously necessary that the strings be arranged to the smallest possible compass, and at the same time they must be so disposed as to afford ample room for the working of the mechanism by which they are to be sounded. In practice, as already stated, the scale designer considers the questions of length and thickness, and the necessity for the latter consideration will be obvious when it is remembered that in a seven-octave piano, supposing the scale to start with a string 2 in. long, the length of the string at the seventh octave above would be 256 in. or 21⅓ ft., which would of course be out of the question within the compass of an ordinary piano. Hence, instead of going on increasing the length of his strings, the piano-maker thickens them, using progressively thicker wires, and finally wire around which thinner wire is wrapped.

The art of laying down a good piano scale involves the attaining of the theoretically highest possible intensity of tone in the instrument. It is a very complicated work, dependent on a multiplicity of contingencies. The marked improvement in the manufacture of steel wire in its capacity to withstand torsion, and to sustain very considerable strains until the limit of elasticity is reached, necessitated the undertaking of new investigations into its properties. With this object, in 1869 Mr. Theodore Steinway constructed a machine for the purpose of testing the tension of steel strings, and by the aid of this obtained data by which he was enabled to correct scientifically the scales in use. The results of these experiments are of especial interest. Steinway's testing machine was used by

the musical jury of the Centennial Exhibition of 1876 to select for awards the best of the exhibited piano strings. The following table shows the sizes of the steel wire generally used for smooth or unwound strings, and its resisting power against the minimum and maximum tension:*

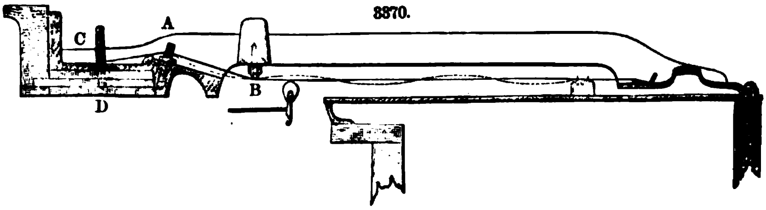
Table showing Tensions in Piano Wires.

SIZES OF STEEL WIRE, NOS.	Diameter, in Millimetres.	MINIMUM, in English Pounds.	MAXIMUM, in English Pounds.	SIZES OF STEEL WIRE, NOS.	Diameter, in Millimetres.	MINIMUM, in English Pounds.	MAXIMUM, in English Pounds.
12............	0.725	160	180	18............	1.025	300	320
13............	0.775	180	210	19............	1.075	330	340
14............	0.825	220	230	20............	1.125	335	[illegible]
15............	0.875	230	250	21............	1.175	390	400
16............	0.925	240	280	22............	1.225	400	400
17............	0.975	280	300	23............	1.3	450	450

The maximum period of vibration of a string does not coincide with the limit of elasticity, and this again is not coincident with the breaking point. While in good material these points approach each other very closely, they differ in pounds very considerably in an inferior article. It is also of very great importance to maintain proper relations between the elasticity of the sounding body and the tension brought to bear on the strings, as otherwise the power of the transverse vibrations of the strings would not be (as they should) transformed into movements of molecules producing sounds, but would simply develop heat and operate destructively on the sounding-board. In this connection it is to be understood that vibrations of strings, when transmitted through the air only, cannot be heard. A string suspended above an isolating elastic cushion, to which string is attached a weight producing strains similar to those above enumerated, does not when struck produce an audible sound. The vibrations become perceptible only through the appliance of a resonating board offering large vibrating planes, and this is called the "sounding-board" in a pianoforte. This sounding-board must be built up out of suitable and very carefully selected material, and constructed in such a manner that the long and wide waves of the lower notes find therein their corresponding modules of elasticity. These being shortened in double progression from octave to octave, the movements of the strings doubling in rapidity in the same ratio, a correctly constructed sounding-board offers the somewhat paradoxical peculiarity that the thinnest and shortest strings require a considerable increase in the thickness and rigidity of the board. The aggregate tension on the strings of the smallest upright piano is 20,000 lbs. In the large concert grand piano it reaches 66,000 lbs. The sound given by a vibrating string is due not only to the fundamental vibrations, but to partial vibrations which divide themselves *ad infinitum* (called overtones by Tyndall), adding to the richness of tone, though surpassing considerably in their pitch the capacity of the human ear. In a properly constructed scale these factors maintain proper relations to the sounding body. Mr. Theodore Steinway has determined that the capacity of a string to make energetic transverse vibrations is augmented by an increase in the tension, if such a string is brought into connection with a sounding-board, the edges of which are subjected to compression. In short scales, the transverse vibrations of strings are retarded, or the pitch lowered, by winding around the strings a specifically heavier metal than steel.

The most notable feature in the Steinway scale is "the duplex" arrangement, which is described as "a second scale of exactly and mathematically proportioned and shortened length, added to the principal scale. This second or duplex scale is applied between the tuning-pins and the end points of the strings upon the wrest-plank." Fig. 3370 shows the string and the vibrations into which it falls on

3370.



being struck by the hammer. The duplex scale of a Steinway grand piano is here between *A*, the agraffe pin, and *B*, the "capo d'astro" bar. The advantages gained by this device are more full and harmonious tones, and the avoidance of dissonances in the partial overtone vibrations. The inventor states that "the intrinsic elasticity of the treble strings, which in proportion to their diameters are greatly strained, is reinstated by means of the duplex scale, which divides the string at its termination behind its fixed resting point mathematically by 2, 3, 4, 6, 8, etc. The transverse vibration of the string produces the principal or fundamental tone. This vibration is transmitted elastically over the crossing or fixed point, and is caused to divide itself into partial tones or overtones."

The Chickering Scale, the manufacturers state, is rather the result of long experience in scale construction than an outcome of abstract investigation. The most noteworthy of the scales claimed by Messrs. Chickering & Sons is the so-called "circular scale" for square pianos. By drawing the

* The minimum tension is the lowest point to which a string can be brought and preserve its tone. The maximum tension is said to be reached when the string has been stretched to a point above which, if subjected to a heavy touch, it will break.

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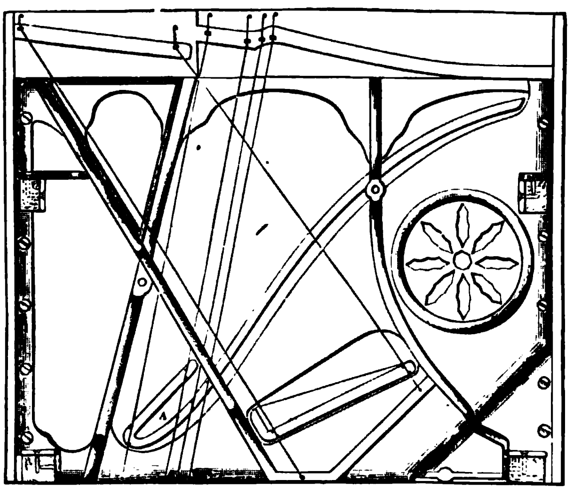
THE STEINWAY GRAND PIANOFORTE.

scale on an arc of a circle or ellipse, the distance between the strings on the hammer-line is increased, and thus more room is given to the hammers.

In actually constructing the scale, the designer generally begins with the highest A note, which may be say 2 inches in length, and which is of No. 14 steel wire. The first line put on paper is the hammer-line, which joins the points at which the hammers controlled by the keys will strike the strings. Along this transverse line the strings are equidistant. Having decided on the length of his highest A string, for example, the designer prepares a thin strip of board, on which he marks the length of the string an octave lower, then that of the string another octave further down; and in this way he gradually lays off on his strip the lengths of all the strings. Of course the general arrangement of the strings and their lengths—or rather the length of the first string, which forms a base for that of the others—is determined upon in accordance with the style of the piano. In the grand and square piano the strings run horizontally; in the upright they are placed vertically. Having laid out his string lengths, the designer then marks the curve which one series of ends of his strings make when the other set of extremities are brought to a straight line. This results in grouping them in a form identical with or approximating that familiarly known as the harp. In grand pianos the inner or remote ends of the strings run in a curve representing the curved side of the harp, the treble strings lying to the right hand. In squares, usually, the harp curve is represented by the ends of the strings toward the right-hand side of the performer, and lying nearer to him. The ends of the strings corresponding to the straight side of the harp thus lie in grands in front, terminating in this case however in a less marked curve; and the like extremities in the squares, which until recently always terminated in a straight line, lie to the left hand and back of the instrument. Nearly all modern pianos possess the "overstrung scale," which was used in the Steinway piano in 1855, in which the strings of the bass notes, instead of being stretched in the same horizontal plane as those of the treble, are carried over the latter obliquely. This allows of greater lengths of bass strings, and renders it possible to place all the strings farther apart, so as to afford more play to the hammers.

Construction of the Piano.—*The Iron Plate.*—In pianos of the largest size the sum of the tensions of the strings, when stretched in attuning, reaches 33 tons. Hence the framing, or those parts within the case which serve as a strut or stretcher between the ends of the strings, and which are to resist this enormous pull, must be made correspondingly strong and rigid; since by any gradual yielding under the pull of the strings their lengths and tensions, and hence their tone, must undergo proportionate change. In the earlier instruments having small strings, the frame was of timber only. With the progress of metallurgy and the gradual introduction of iron structures, this metal came to be used for the plate or platform which receives the strain of the strings. Upon this part of the instrument centres a large number of the patented devices which enter into modern piano construction, and it forms the ground of much of the controversy between rival manufacturers. It seems to be undisputed that in 1825 Alpheus Babcock obtained a patent in the United States for a cast-iron ring of harp shape, used in a square piano in order to increase the power of its resistance to the strings. The Messrs. Meyer of Philadelphia claim that they in 1833 introduced a piano with a full cast-iron frame. This claim was allowed by the Centennial Commission. (See official report.) It is not necessary to enter into any discussion on the subject, other than to state that Mr. Jonas Chickering was one of the first to recognize the value of Babcock's device, and to modify and adapt it to practical use in the pianoforte. Numerous improvements in its construction have been devised and patented by Messrs. Steinway & Sons, culminating in the form of frame represented in the grand piano, Fig. 3371, and in the upright piano, Fig. 3373. In both forms it will be observed that the edges of the plate are lower than the middle portion, producing a so-called cupola form, and that the bars are disposed so as to lie parallel to the direction of the strings. The manner in which this frame overlaps the wrest-plank *D* is shown in section at *C* in Fig. 3370. It will be noted that two cross-bars are used, one forming the angular projection of the wrest-plank part of the frame above noted under the strings, and the other nearer the middle of the piano, passing over the strings. It is claimed that the longitudinal bars abut with straight resisting pressure directly against the upper cross-bar, and that the weak spot in the bracing near the wrest-plank portion, due to the fact that the level of the tension is under the brace level, is thus avoided. On the under side of this cross-piece, or *capo d'astro bar*, as it is called, are placed agraffes which furnish a bearing to the strings. One result of this construction is stated to be that the suspended wrest-plank can neither be raised not depressed by the largely increased pull of the strings. Figs. 3372 and 3373 represent the cupola

3372.



frame of the upright piano, Fig. 3373 showing the strings in place. Compression-screws press the sounding-board against the metal frame, and the latter rests directly upon the board and descends at certain points between the braces of the wooden case; here the compression-screws bring to bear a pressure sidewise against the underbracing of the sound-board. The Steinway iron frames are cast at the makers' own foundry from metal capable of sustaining a strain not less than 5,000 lbs. per square centimetre. The Chickering frame differs from that above described in the absence of a capo d'astro bar. The agraffes are screwed in a solid iron flange on the under side of the frame parallel with the wrest-plank, and an additional flange is also cast upon the under side, running parallel with the hammer-line, to give greater strength and stiffness to the head-block. A strong construction is said to be obtained by using a double thickness of iron in the rear of the agraffes, where the pin-block bolts against the frame.

3373.

The Sounding-Board.—When a vibrating wire is at rest, its tension is necessarily somewhat less than at any other moment, since in order to assume its curved segmental form it must be a little elongated, which involves a corresponding increase of tension. Hence the pegs by which the ends of a wire are attached to the sounding-board are submitted to an additional strain twice during each complete segmental vibration. The sounding-board, being purposely constructed of the most elastic wood, yields to the rhythmic impulses acting upon it, and is thrown into segmental vibrations like those of the wire. These vibrations are communicated to the air in contact with the sounding-board, and are then transmitted farther in the ordinary way. The amount of surface which a wire presents to the air is so small, that but for the aid of the sounding-board its vibrations would hardly excite an audible sound. The sounding-board therefore plays the same part as the hollow cavity of the violin, and is in fact a solid resonator. The wood used for sounding-board construction is spruce. An immense supply of this wood is kept on hand. The logs are quartered, and the boards are cut from them so as to have a perfectly smooth surface grain, and to measure five-eighths of an inch in thickness. The lumber thus prepared is kept under cover for several years, until needed for use, when it is subjected to the heat of a drying-room. The boards are jointed together to a bevel, the thickness varying from a quarter to three-eighths of an inch at the treble portion. This "table" is next sawed into the proper shape, this depending upon whether it is to enter into a grand, square, or upright piano. After shaping and drying, the bars which brace the sounding-board on the bottom or rear are firmly glued in place, and the bridges are secured on the upper or front side. The bridges are formed of numerous layers of thin maple, and receive iron pins which hold the strings in place. In the Steinway piano a "ring bridge" is used. This consists in curving the bridge *A*, Fig. 3372, back upon itself. The advantage claimed for this is a greater evenness of tone in the transition from the steel to the covered strings.

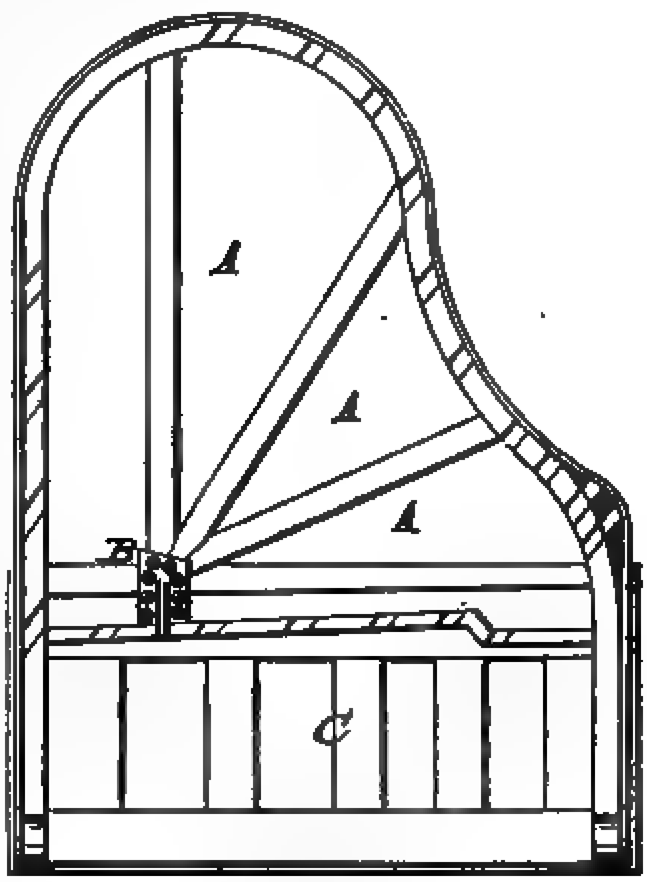
The Case.—The principal portion of the case is the skeleton or bottom framework, which supports the sounding-board, the iron plate, and the strings. In the square piano it consists of a bottom built up of a square frame filled in solid, and covered above and below with smooth boards. Above this are secured the under-blocking and the wrest-piece.

In Fig. 3374 is represented the case of a small Steinway grand piano, which exhibits a new method of manufacture. The entire case is formed of two bent and continuous rims of wood, which at the short bend on the right-hand side run in different directions. This frame is strengthened by three braces, which are secured to a metal shoe *B*, abutting against the metal part of the wrest-plank. The portion *C* beneath the key-board is solid. Generally the curved rim of a grand piano is built up of several thicknesses of thin wood successively bent around a form. Messrs. Steinway & Sons have recently succeeded in bending the entire rim of a single plank 1¾ inch in thickness upon a specially devised press. The same firm also use an ingenious vertical planer, which consists of a planer-knife attached to a rapidly rotating cylinder, for smoothing the exterior surface of piano cases. The entire case of a grand piano is dressed at a single operation, the workmen simply guiding it in contact with the knife. In cutting veneers of ordinary wood in the same factory, huge logs of the desired wood are first steamed, and then chucked bodily in a large machine, and caused rapidly to rotate. While turning, a horizontal knife is brought in contact with the wood, and made to slice off

the latter in thin sheets some 12 ft. in length. The choicer grades of wood, especially rosewood, are cut into veneers by large circular saws which produce very fine work.

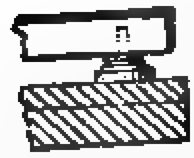
The portions thus far described having been completed, the sounding-board is glued in, and the iron frame adjusted; this last is placed in the skeleton of the upright piano, and in the completely finished case of the grand or square instrument. It will be seen, therefore, that at this stage of the manufacture the cabinetmaker's work is virtually completed. The cases are veneered, and are subjected usually to numerous varnishings, with occasional rubbings with pumice or rotten stone. The legs and lyres, which are of whitewood, are roughly carved out by a carving machine, and subsequently finished by hand. These are always stained and grained in imitation of the wood of the case.

3874.



Strings.—The wire used for strings in the piano is of steel, ranging in size in grand pianos from No. 13 to No. 25. In order to increase the thickness of the strings used for the bass notes, these are wrapped with wire either of iron or copper, varying in size from No. 16 to No. 40. In upright pianos, the nine lowest notes of the bass are double-wound. The machine for applying the wrapping consists simply of two rotating hooks actuated very rapidly by suitable gearing, between which the wire is fastened. At the point where the winding on of the outer wire is to begin, the inner wire is slightly flattened by a blow of the hammer. The end of the wrapper is thus easily secured, and as the main wire rotates the coils of the wrapper multiply until a sufficient surface is covered, when the wrapping wire is divided through its coming in automatic contact with a stationary knife.

The stringing consists in placing the wires in proper position over the iron plate and sound-board. Where but a single wire is employed to produce a note, it is fastened first to the hitch-pin, which, as already explained, is inserted in the iron frame; then it passes over the bridge, and is held in position by the bridge-pins; thence it passes through the agraffe, and finally is secured and twisted around the tuning-pin, which, passing through the iron plate, has its bear-
ık. Each of the three strings which are tuned in unison
.e in a grand piano is thus secured. Where a double
nds to a note, then the ends are fastened to separate
loop or bight is passed around the hitch-pin.
usual modes of giving strings a bearing, namely: the
od bridge, and the various forms of agraffe. In the
piano both the wire and wood bridges are used. Nearly
ffes. The wire bridge is a strip of wood having a wire
e string is passed, and then is led under a strip of brass
d to the tuning-pins. This form of bridge is necessitated
ruction of the Chickering upright piano, and it is more
e high notes to give brilliancy of tone. The wood bridge
ood having pins in it, between which the strings pass.
een the subject of a large number of improvements and
Essentially it is a stud or pin pierced with two or three
and made fast below the wrest-plank. The device used
ano is known as the double-bearing agraffe, the orifices
y placed at such an angle that a double bearing to the
In the Steinway piano, the capo d'astro agraffe already
stead of wire and wood bridges. It permits the estab-
lex scale in one separate and independent piece, under
nk, subjected to the effects of different temperatures,
ink without disturbing the length of the scale. This agraffe is made of copper alloy, and is strengthened by a steel cap or facing along its upper edge.



It is the work of the stringer to apply the strings as we have described. As he fastens each string in place, he "chips it up," as the operation of sounding it to see that it attains approximate pitch is termed. This is done simply by snapping the string with a bit of wood. Simultaneously with the operations already described, the work of action- and key-making is progressing, and the iron frame adjusted.

The Action is the machinery through which the impulse given by the finger of the performer is

transmitted to the string of the instrument. The operation of any action is as follows: 1. The damper is lifted from the string. 2. The hammer is caused to strike and fly back. 3. The damper is replaced the instant the finger is lifted from the key. It will be evident that the prime requirement of the action is instantaneous response to the pressure of the finger, noiseless and certain operation; and besides this, it must consist of the fewest possible number of parts.

Fig. 3375 represents the Steinway upright piano action, the operation of which is as follows: On pressing the key, the riser *A* is lifted, thus raising the inner end of the pivoted jack-bed *B*. To the jack-bed is secured the jack, the upper end of which abuts against the leather-covered shoulder on the hammer-butt *C*. To this butt is attached the hammer *D*, which is thus thrown forward against the string. Connected to the jack-bed is the fly which touches the damper-trip *E*. This connects by a rod with the damper *F*. It will be seen that the effect of pushing down the key is first to remove the damper from the string, and then to throw forward the hammer. The hammer immediately recoils, but is held from coming back to its normal position so long as the key is held down by the back-catch bunter coming in contact with the back catch *G*, which moves up to meet it. The hammer is thus held from vibrating as long as the key is held down; but the moment the key is released, the hammer falls back against the hammer-rest *H*.

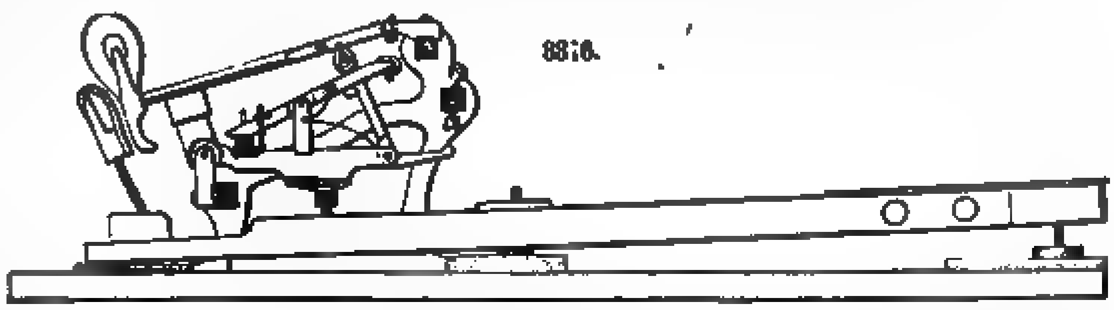

3376.

Fig. 3376 represents the Steinway repetition grand action, and also shows a section of the tubular frame referred to farther on.

Fig. 3377 represents the form of upright action made by Messrs. Dunham & Sons of New York. Its construction, which is notably simple, will be easily understood from the engraving.

3377.

3378.

There is scarcely any portion of the piano in which more accurate work is required in the construction than the action. It is composed, as already indicated, of a large number of parts, but not one of these can be slurred over or imperfectly made. The wood used is apple, holly, and maple, cedar being employed for hammer-stems in the upper notes, where lightness in the movement is essential. As each note has special mechanism, it follows that any complete action consists in the seven-octave piano of 88 individual actions—88 hammers, 88 jacks, etc., etc.; and consequently there is occasion for a large number of pieces to be made exactly alike. The method in which this is done will be readily understood by taking hammer-heads as an example. A strip of wood is passed through a moulding machine, and is thus formed of a cross-section of the shape of the head (see Fig. 3378). It is then sawed into pieces of the proper width of each head. These pieces are secured side by side, and while they are thus held the felting which is to cover them is glued on in a continuous strip. In the Steinway factory the felting is cut as shown at *B* in Fig. 3379, and the hammers are placed over it as at *A*. The hammers are then forced down by a screw-press, and at the same time the felting is brought up around the sides of the hammers, which are left in the press until the paste is dry, after which the felting is divided, separating each hammer with its covering. Hammer-butts are made in precisely the same way. There are a number of operations performed on the parts of an action which it is hardly possible to describe in detail. Ingenious boring lathes are used for drilling the pivot-holes, and these last are bushed with felting. A special machine has been devised for drilling a bearing from opposite sides simultaneously, so as to avoid the minute inaccuracy due to the possible bending of a drill hardly three-quarters of an inch in length in passing through the wood. One workman inserts the springs, another the pins, and thus the labor is differentiated down to a remarkable degree—a necessary consequence of the repeated handlings the material has to go through. Some idea of the variety and number of the manipulations may be

gleaned from the fact that the handlings of the parts of a complete upright piano action aggregate some 27,000.

The best felting used for hammer-heads, etc., is made of Silesian wool, and is prepared in sheets of about 30 × 40 inches in dimensions. Each sheet is made varying in thickness from 1 inch to one-eighth of an inch. A strip cut across the bevel of the sheet thus gives the different thicknesses applicable to a complete set of hammers, the hammers for the bass notes having the thickest covering. The reason of this is obvious when it is remembered that the increasing weight of the hammer allows of a harder blow being given, and thus of the heavy strings being thrown into more prompt and perfect vibration. There are always two, and in many cases three coverings on a hammer-head. The first is of hard felt, the second of soft white felt, and the third, found most frequently in square pianos, is of a finely dressed buckskin. The best felt is now made in America.

For supporting the action, instead of using wooden bars, in the Steinway pianos brass tubes filled

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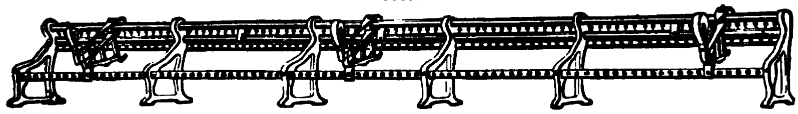

with wood are employed. This combination is claimed to give increased strength, and to be unchangeable by atmospheric influences. The tubes are soldered to metal hangers in upright actions, and to metal standards in the grand action, as shown in Fig. 3380.

The Keys are made of pine boards cut in lengths suitable to the form of piano under construction, and then jointed edge to edge. The dimensions of the composite board thus prepared must in width be exactly equal to the proposed length of key-board, and in length sufficient to extend back under the action. The middle boards of the piece have a grain running directly crosswise the piano, from front to back. The boards at the sides are jointed at an angle, so that their grain runs in diverging directions. This board is first carefully examined to see that the joints are perfect, and is then marked off, the narrow front portion into keys exactly as they appear in ivory on the piano, and the wider rear part to continuations of the same. It passes to a workman, who glues a strip of ivory along the front edge. A second operative then similarly attaches the pieces of ivory on the upper surface, which form the wide front portions or heads of the white keys (outside the line of black keys); and when this is dry, he applies the narrow strips which form the rear or "tails" of the same. The best wood for key-boards is the American white clear pine. Holes are then made in the board for the pins on which the keys balance, and then the entire board is cut up into the several keys. Upon those of the latter which are to be black or upper keys of the scale, pieces of ebony are glued. The completed set of keys is then adjusted on the pins already inserted in the base-board upon which they are to rest in the piano, and each key is carefully balanced, so that the distance each will descend when pressed by the fingers shall be the same.

Assembling and Tone-regulating.—The various portions of the piano as described are all assembled under the hands of the finisher. This workman adjusts the action, and cuts down the felting on the hammer-heads, so that their easy working is secured. The instrument is then trimmed, and at this time the pedals are inserted. The action of the two pedals is as follows: In the grand piano, the soft pedal shifts the key-board and associated hammers in such a way that each hammer acts on two of the wires corresponding to it, instead of on the complete set of three wires. In upright pianos, the same pedal moves the hammer-rail nearer to the hammer, so that the latter is carried nearer to the string, and hence does not strike it with so forcible a blow. In the square piano, the soft pedal controls a bar to which are secured pieces of felt—or buff stops—which by its action are brought forward so as to come between hammer and string, and thus deaden the blow of the hammer. The loud pedal in all pianos simply raises the dampers from the strings. In the Steinway piano a third pedal, known as the sostenuto or tone-sustaining pedal, is employed, which consists simply of a horizontal flanged bar which is rotated on its axis by the pressure upon the pedal. The effect of rotating the bar is to cause its flange or projecting portion to engage with and hold up from the strings such dampers as may be raised by the player pressing upon the keys, the tones corresponding to which he wishes prolonged, and which leaves both hands free to play other notes.

After the piano is, as it were, put together, it passes to the hands of the toner, and by his manipulation of the hammer-heads it is given a singing, resonant quality of tone. This is done in various ways. When it is desired that the felt on the hammer-heads shall be softer, needles are used to prick it up. In square pianos, small pieces of fine leather are glued over the felt. Generally a skillful toner can produce any desired quality of tone, ranging between one that is soft and singing and one that is hard, sharp, and brilliant. Before toning, the instrument is carefully examined and regulated. During all the processes following the stringing the piano is frequently tuned, and, in fact, it is thus treated both before and after passing into the hands of each workman. After toning, the piano is again inspected, and then in complete form is sent for a thorough final examination by an expert. The repeated tunings have by this time brought the strings down to firm bearings, and the mechanical portions have become well settled and adjusted to their places, so that nothing remains to be done but to subject the instrument to a general scrutiny for defects which may have escaped previous notice. If any are found, the piano is returned to the proper workmen, and the faults are corrected. If none are noted, it receives a final tuning, and is sent to the warerooms. G. H. B.

PICKAXE. See Axes and Mine Appliances.

PILE-DRIVING MACHINES. In all cases, whether manual or steam labor is employed, the pile is driven by a blow which is given by a ram or monkey. The sinking of the pile depends on condi-

tions of tenacity and consolidation of the ground into which it is driven, and these are too varied and complicated to be capable of general expression. The following table has been calculated according to the laws of falling bodies (see DYNAMICS), showing in one column the time of descents in seconds of any ram falling from 1 to 40 ft., and in the other the force in tons with which a ram weighing 1 ton will strike in falling from the same height. The force of the blow given by a ram of any other weight than 1 ton may be ascertained by this table, by multiplying the number in the column headed "Force in Tons" by the weight of the ram. Thus, if it is required to determine the force of a blow given by a ram of 16 cwt. falling from a height of 30 ft., opposite 30 we find the tabular number 43.9; hence, $16 \times 43.9 = 702$ cwt. = 35 tons 2 cwt., the force required.

Table showing Energy of Fall of Ram weighing 1 *Ton.*

FALL OF RAM IN FEET.	Time of Fall in Seconds.	Force in Tons for a Ram weighing 1 Ton.	FALL OF RAM IN FEET.	Time of Fall in Seconds.	Force in Tons for a Ram weighing 1 Ton.	FALL OF RAM IN FEET.	Time of Fall in Seconds.	Force in Tons for a Ram weighing 1 Ton.	FALL OF RAM IN FEET.	Time of Fall in Seconds.	Force in Tons for a Ram weighing 1 Ton.
1	0.25	8.0	11	0.83	26.6	21	1.14	36.7	31	1.39	44.6
2	0.35	11.3	12	0.86	27.8	22	1.17	37.6	32	1.41	45.4
3	0.43	13.9	13	0.90	28.9	23	1.20	38.5	33	1.43	46.1
4	0.50	16.0	14	0.93	30.0	24	1.22	39.3	24	1.45	46.8
5	0.56	17.6	15	0.96	31.0	25	1.25	40.1	35	1.48	47.4
6	0.61	19.6	16	1.00	32.1	26	1.27	40.9	36	1.50	48.1
7	0.66	21.2	17	1.03	33.1	27	1.29	4 .7	37	1.52	48.8
8	0.70	22.7	18	1.05	34.0	28	1.32	42.4	38	1.54	49.4
9	0.75	24.1	19	1.09	35.0	29	1.34	43.2	39	1.56	50.1
10	0.79	25.3	20	1.11	35.9	30	1.37	43.9	40	1.58	50.7

Opinions vary as to the best weight of ram. A heavy ram with a short fall, however, is to be preferred to a light one with a long fall, the latter being more likely to split the pile; the blow given by the former is more solid, and, having a shorter fall, the blows are delivered quicker. In machines in which the ram is raised by hand, it is not advisable to use one of greater weight than 1½ ton, as it then becomes unwieldy. Generally, however, the weight of the ram should be proportional to the sectional area of the pile to be driven. Piles having a diameter of 10 to 14 in. require to be driven with a ram weighing from 1,000 to 1,700 lbs. Sheet piles, with a breadth of 9 in. and a thickness of 3 or 4 in., require a ram weighing from 1,000 to 1,700 lbs. The weight of a ram required for a pile of any given dimensions with a certain fall may be determined from the following equations: Let F equal the height of the fall in feet, W the weight of the ram in pounds, B the breadth and T the thickness of the pile in inches. Let L represent the length of the pile in feet and W_1 its weight in pounds. Then for the value of W we have $W = W_1 \left(\frac{F \times W_1}{5\,B\,T\,L} - 1\right)$. If the pile is square, putting S for the length of one of the sides in inches, the formula becomes $W = W_1\left(\frac{F \times W_1}{5\,S^2\,L} - 1\right)$. By the same formula, by simple inversion and reduction, the value of F, or the fall proper for a given weight of ram, can also be ascertained.

Steam is almost exclusively used as a means for raising the ram in modern pile-driving machines.

The Nasmyth Pile Driver, Figs. 3381, 3382, and 3383, is an example of this class of apparatus. Fig. 3381 is a front and Fig. 3382 a side elevation, and Fig. 3383 a sectional view. A is the platform on which the machine is erected, formed of massive timbers and secured by iron brackets B, in which locomotive wheels a are fitted to work upon rails disposed parallel and close to the line of piling on which the machine is desired to operate. C is the vertical guide-pole, bolted to one side of the platform and counterbalanced by the boiler placed at the other side. D is a strong timber support, and $b\,b$ are adjustable stays. On the summit of the upright C are the brackets E, which carry a chain-pulley over which works the chain c, one end of which is passed round a barrel worked by the engine, and the other end is attached to the pile-driving apparatus. The driving engine consists of a cylinder F, Fig. 3383, bolted to the pile-case G. The interior surface of the latter serves as a guide for the hammer-block, while it is itself guided along the upright C by pieces d, which embrace the projecting slips of iron e bolted in front of the upright throughout its entire length. The lower end of the pile-case is open, to admit the head of the pile, and is furnished with cast-iron jaws bolted to its interior surfaces; these are so formed as to rest upon the shoulders of the pile H, which, if we suppose the chain-barrel to be left free to revolve, thus becomes the sole support for the weight of the whole mass of the driving apparatus. By these arrangements it will be seen that as the pile is, by successive steps, forced into the ground by the action of the hammer (the chain-barrel being thrown out of gear with its driving apparatus during the process), the pile-case with all its appendages, weighing about three tons, is left at liberty to bear upon the shoulders of the pile, and follow down along with it, while at the same time, and by the same means, the pile itself is guided into a vertical course. I is the steam-boiler, J the steam-dome, and K the jointed steam-pipe leading to the cylinder F. Referring to Fig. 3383, L is the steam-valve chest, within which is the D-valve k; l is the exhaust-port. At m are made numerous small holes in the cylinder to allow of escape of steam in case the piston should rise above them and thus reach too great a height. M is the piston; N is the piston-rod, having at its lower extremity an enlargement n for the purpose of affording means for a slightly elastic connection by hard-wood washers, between the piston-rod and hammer-block. O is the hammer-block, consisting of a rectangular mass of cast iron weighing 30 cwt., and adapted to slide freely within the pile-case G. At its upper extremity is a recess in the form of an inclined plane $o\,o$, for the pur-

pose of acting upon the valve-lever so as to permit the escape of steam after it has raised the hammer to a sufficient height. *P* is the hammer fitted to the block by a wrought-iron key *o*. *Q* is the latch-lever. *p* is a small solid piston working in a cylindrical part of the valve-chest, and attached to the valve by a short connecting-rod. Its under surface is constantly acted upon by the pressure of the steam within the valve-chest, so as to cause the steam-valve to assume the position indicated

3381. 3382.

in Fig. 3383, unless counteracted by a superior force. *q* is the valve-spindle; *r*, the valve-lever; *s*, the trigger, the function of which is to keep the steam-valve in such a position as to prevent the admission of steam into the cylinder during the descent of the hammer-block; *t*, the parallel bar against which the latch-lever acts at the termination of the stroke, for the purpose of releasing the valve-spindle from the trigger, in order to allow the steam to be admitted for a fresh stroke; *u*, the parallel-motion bell-cranks; and *v*, a buffer-box for restricting the travel of the valve. The machine is

rendered locomotive by the horizontal engine *R*, which communicates with the supporting wheels by suitable gearing. *H'*, Fig. 3381, is the pile, shown suspended by the chain *d* and ready to come under the action of the driving machinery, which is as follows:

The pile-case *G G*, with its attached machinery, is lowered down over the head by reversing the small engine *R*, so that the jaws *f f* rest upon the shoulders of the pile, which sinks down into the ground by the effect of the superincumbent weight, till it has reached soil sufficiently firm to support it; this is indicated by the chain *c c* becoming slack. The pinion *y* is then thrown out of gear, and the steam is admitted into the driving-cylinder *F* by turning the handle *i*. The hammer-block *O* is by this means raised till the inclined plane *o' o''*, coming in contact with the valve-lever *r*, causes

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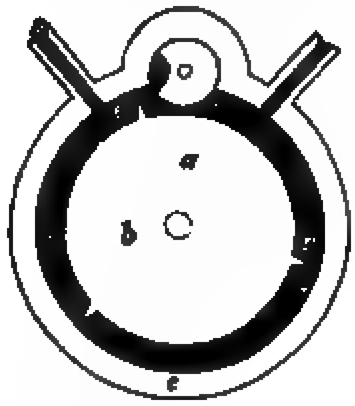

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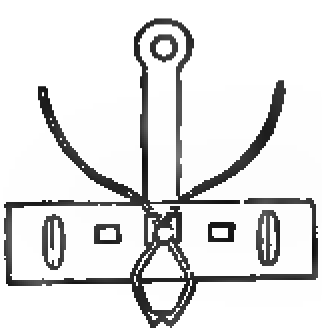

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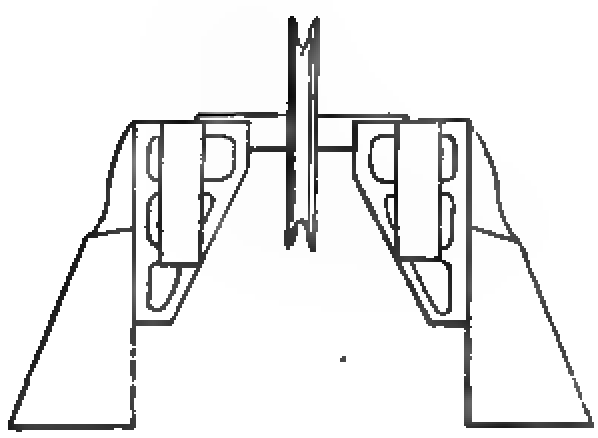

the valve *k* to assume a position which allows the steam which had served to raise the hammer to blow out into the air, and the hammer descends and discharges its momentum in the form of an energetic blow on the head of the pile. During the descent of the hammer-block, the steam-valve is retained in its proper position by the action of the trigger *s*; but by the effect of the concussion upon the head of the pile, the valve-spindle is relieved from contact with the trigger, and the steam-valve assumes the position indicated in Fig. 3383, in which circumstances the steam is allowed to act freely under the piston, for the purpose of again raising the hammer.

The ordinary form of pile-driver used for sinking short piles for building foundations consists simply of an upright guiding-frame for the hammer or ram, as shown in Fig. 3384. The hammer is

grasped by tongs shaped as shown in Fig. 3385, the upper arms of which, when the hammer is raised to the top of the frame, enter between inclined planes, as shown in Fig. 3386. The arms are thus brought together, causing the lower jaws to open and release the hammer, which descends upon the pile. The lifting is done by a small engine, to the barrel of which the hoisting rope is taken after being led over a pulley at the summit of the frame.

Shaw's Gunpowder Pile-Driver is represented in Fig. 3387, in sectional elevation and plan. *M* is a mortar of cast steel, and *N* a cast-iron weight. The piece *M* is elliptical in section, as shown, and embraces the head of the pile by a recess in its lower part. In the upper part is a cylindrical opening in which the charge is placed. The diameter of this opening is $5\frac{1}{2}$ in., and its depth $24\frac{3}{4}$ in. The weight is cylindrical, with a recess in the upper part $8\frac{1}{4}$ in. in diameter and $21\frac{5}{8}$ in. deep. It carries below a wrought-iron rod, terminating in a piston with steel rings *P*, making a tight fit in the mortar *M*. In the under part of the cast-iron cross-piece *T* of the frame is fixed a second piston *O*, corresponding to the opening in the weight *N*. The brake employed for stopping the latter is composed of a T-iron *F*, $8\frac{1}{4}$ in. by $2\frac{9}{16}$ in. by seven-sixteenths of an inch, with planed faces, held in position by parallel jointed levers *L*, and moving upon the supports fixed to the bracing of the main beam. The weight is adapted on its rear face to receive the action of the brake, which is worked from below by a lever brought down to the carriage. The total weight is about 6 tons. The machine is worked by two men, one for controlling it, and the other for introducing the charge. Six or eight workmen are also required to handle the piles and move the machine. The weight *N* being suspended so high that the plunger has at least 39 in. elevation above the mortar *M*, which rests on the pile to be driven, the man working the brake gives the order to fire. On this, the second attendant places the charge in the mortar, the brake is released, and the weight falls. On the arrival of the plunger *P* in the mortar, which it fits closely, the air is compressed, forming an elastic cushion, the action of which is exerted on the pile, and helps to drive it by pressure. The air, thus compressed from 20 to 25 atmospheres, is heated sufficiently to ignite the charge. Then to the force of the explosion has to be added that due to the expansion of the gases, and the pile is forced downward, but without any shock.

A full description of this apparatus will be found in *Engineering*, xxi., 409. See also article "Pile-Driver," in Spon's "Dictionary of Engineering," and a series of papers on the "Cost of Driving Piles," *Engineering*, xxiii. For general data on pile-driving, see Rankine's "Civil Engineering." As to use of piles for foundations, see FOUNDATIONS.

PILLOW-BLOCKS. See PEDESTALS.

PINCERS. See FORGING.

PISTOL. See FIRE-ARMS, CONSTRUCTION OF.

PISTONS. A piston or plunger is a sliding piece which is either driven by fluid-pressure, or acts against fluid-pressure as a resistance. Pistons and plungers are commonly circular in section, and are guided by cylindrical bearing surfaces so as to reciprocate in a straight path. Other forms of piston are occasionally used. A *plunger* is a single-acting piston—that is, a piston receiving the action of the fluid on one face only; and it is guided, not by the cylinder itself, but by a stuffing-box in the cylinder-core. The bearing surface of the plunger, therefore, requires to be longer than the stroke. A large hollow piston-rod is termed a *trunk*. The pistons of pumps are often termed *buckets*.

A piston may be simply turned to fit the cylinder accurately; but, however good the fit at first, the wear of the cylinder and piston will gradually enlarge the clearance between them, and the leakage will steadily increase. If a series of recesses are cut around the piston's circumference, the leakage for any given width of clearance space is less, because the fluid loses its energy of motion at each sudden enlargement of the section of the annular space between the piston and cylinder through which it is escaping. Pistons of this kind are used for quick-running pumps, where a small leakage is not very prejudicial. In early forms of pistons iron packing-rings were employed, forced out by hemp packing behind them, which packing was tightened by a projecting lip on the follower. The rings in modern practice are commonly set out by flat steel springs, which are either adjustable by set-screws, or have sufficient elasticity to act without adjustment. In cases where the springs are

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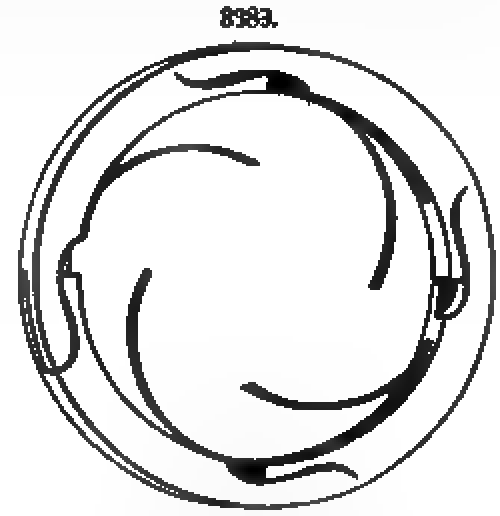

adjustable by set-screws, great care is necessary in setting out the rings, since this operation is generally performed when the cylinder is cold, and the rings expand considerably when heated. In some instances, as in the piston of the Porter-Allen engine, no springs are used, the only packing consisting of light rings, set out by their own elasticity. In another form of piston the packing-rings are set out by the pressure of steam, which is admitted to the interior of the piston.

In Wheelock's piston-packing, Figs. 3388 and 3389, which is largely used in this country, the rings are in sections, joined in such a manner, as is claimed by the inventor, that they can adjust themselves and work without leaks in cylinders that have become worn and have irregular sections.

In hydraulic pistons, cup-leathers are frequently employed. The fluid-pressure acting on the flexible leather cups, aided by their own elasticity, makes an exceedingly stanch joint, whatever the pressure may be. The cup-leathers are usually so arranged that one acts when the piston moves in one direction, the other when the piston travels in the reverse direction.

The following formulæ are given by Unwin ("Elements of Mechanism," London, 1877) for the strength of pistons of wrought and cast iron, regarding them as simple metal disks supported at the centre and uniformly loaded. The thickness would be $= .0051\, d \sqrt{P}$ for wrought iron, and $.0083\, d \sqrt{P}$ for cast iron; in which expressions $P =$ greatest difference of the pressures on the two sides, estimated per unit of area, and $d =$ diameter of the piston. R. H. B. (in part).

PLANES. The chisel, when inserted in one of the several forms of stocks or guides, becomes the plane, the general objects being to limit the extent to which the blade can penetrate the wood, to provide a definitive guide to its path or direction, and to restrain the splitting in favor of the cutting action. In general, the sole or stock of the plane is in all respects an accurate counterpart of the form it is intended to produce. Although convex surfaces, such as the outside of a hoop, may be wrought by any of the straight planes applied in the direction of a tangent, it is obvious that the concave plane would be more convenient. For the inside of the hoop, the radius of curvature of the plane must not exceed the radius of the work. For the convenience of applying planes to very small circles, some are made very narrow or short, and with transverse handles, such as the plane for the hand-rails of staircases. The sections of planes are also either straight, concave, convex, or mixed lines, and suited to all kinds of specific mouldings, but we have principally to consider their more common features, namely, the circumstances of their edges and guides: first, of those used for flat surfaces, called by the joiners *bench-planes;* secondly, the *grooving-planes;* and thirdly, the *moulding-planes.* The various surfacing planes are nearly alike as regards the arrangement of the iron, the principal differences being in their magnitudes. Thus the maximum width is determined by the average strength of the individual, and the difficulty of maintaining with accuracy the rectilinear edge. In the ordinary bench-planes the width of the iron ranges from about 2 to 2½ inches.*

The lengths of planes are principally determined by the degree of straightness that is required in the work, and which may be thus explained: The joiner's plane is always either balanced upon *one* point beneath its sole, or it rests upon *two* points at the same time, and acts by cropping off these two points, without descending to the hollow intermediate between them. It is therefore clear that, by supposing the work to be full of small undulations, the spokeshave, which is essentially *a very short plane,* would descend into all the hollows whose lengths were less than that of the plane, and the instrument is therefore commonly used for curved lines. But the greater the length of the plane, the more nearly would its position assimilate to the general line of the work, and it would successively obliterate the minor errors or undulations; and provided the instrument were itself *rectilinear,* it would soon impart that character to the edge or superficies submitted to its action. The following table may be considered to contain the ordinary measures of surfacing planes:

NAMES OF PLANES.	Lengths in Inches.	Widths in Inches.	Widths of Irons.
Modeling-planes, like smoothing-planes	1 to 5	½ to 2	⅜ to 1½
Ordinary smoothing-planes	6½ to 8	2¾ to 3¼	1¾ to 2⅜
Rebate-planes	9½	⅜ to 2	⅜ to 2
Jack-planes	12 to 17	2¾ to 8	2 to 2½
Panel-planes	14½	3¼	2½
Trying-planes	20 to 22	3¼ to 3¾	2⅜ to 2¾
Long planes	24 to 26	3¾	2⅝
Jointer-planes	28 to 30	3¾	3¼
Coopers' jointer-planes	60 to 72	5 to 5½	3¼ to 3⅜

The succession in which they are generally used is the jack-plane for the coarser work, the trying-plane for finer work and trying its accuracy, and the smoothing-plane for finishing.

The leading difference between the jack-plane and the trying-plane is in the shape of the iron, as shown in Figs. 3390 and 3391. If the iron of the jack-plane be looked at from the front end of the

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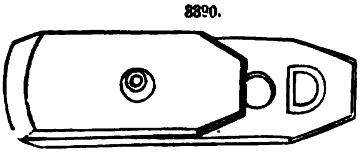

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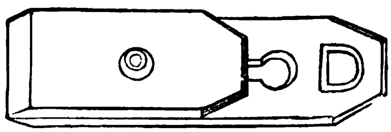

plane, the form of the edge is seen to be curved, as in Fig. 3390; but the iron of the trying-plane is straight, as in Fig. 3391. Upon the curvature of the edge depends the efficient action of the jack. In using the jack, the convex sharp edge is pushed along a horizontal plank, penetrating to a depth determined by the projection of each vertical section below the sole of the plane. The ends of this convex edge are actually within the box of the plane; consequently (sidewise), all the fibres are separated by cutting, and are therefore smooth and not torn. The effect of this upon the entire sur-

* The "iron" is scarcely a proper name for the *plane-iron,* which is a *cutter* or *blade,* composed partly of iron and steel; but no confusion can arise from the indiscriminate use of any of these terms.

face is to render it irregularly corrugated. It becomes, as it were, a series of valleys and separating hillocks, the valleys being arcs from the convexity of the tool, and the separating hillocks the intersections of these arcs. To remove these lines of separation is the object of the trying-plane. This is longer than the jack, because the sole of the plane, which is level, is, so far as its size goes, the counterpart of that which the surface of the wood is to be; further, the trying-plane should be broader than the jack, because its object is to remove the valleys and not to interfere with the wood below the bottoms of the latter. The result therefore of the trying-plane following the jack is, first, to remove all the elevations left by the jack; and second, to compensate by its great length for any want of lineal truth consequent upon the depth of bite of the jack.

The *mouth* of the plane is the narrow aperture between the face of the iron and the *wear* or face of the mortise. The angle between these should be as small as possible, in order that the wearing away of the sole, or its occasional correction, may cause but little enlargement of the mouth of the plane; at the same time the angle must be sufficient to allow free egress for the shavings, otherwise the plane is said to *choke*. In all the bench-planes the iron is somewhat narrower than the stock, and the mouth is a wedge-formed cavity; in some of the narrow planes the cutting edge of the iron extends the full width of the sole, as in the rebate plane.

The amount of force required to work each plane is dependent on the angle and relation of the edge, on the hardness of the material, and on the magnitude of the shaving; but the required force is in addition greatly influenced by the degree in which the shaving is *bent* for its removal in the most perfect manner. The spokeshave cuts perhaps the most easily of all the planes, and it closely assimilates to the penknife; the angle of the blade is about 25°, one of its planes lies almost in contact with the work, the inclination of the shaving is slight, and the mouth is very contracted. The spokeshave works very easily in the direction of the grain, but it is only applicable to small and rounded surfaces, and cannot be extended to suit large flat superficies, as the sole of the plane cannot be cut away for such an iron, and the perfection of the mouth is comparatively soon lost in grinding the blade. Plane-irons are usually ground at the angle of 25°, and sharpened on the more refined oilstone at 35°, so as to make a second bevel or slight facet; the irons so ground are placed at the angle of 45°, or that of *common pitch;* it therefore follows that the ultimate bevel, which should be very narrow, lies at an elevation of 10° from the surface to be planed. In the planes with double irons, the top iron is not intended to cut, but to present a more nearly perpendicular wall for the ascent of the shavings; the top iron more effectually *breaks* the shavings, and is thence sometimes called the *break-iron*. Now, therefore, the shaving being very thin, and constrained between two approximate edges, it is as it were bent out of the way to make room for the cutting edge, so that the shaving is removed by absolute *cutting*, and without being in any degree split or rent off.

Some variation is made in the angles at which plane-irons are inserted in their stocks. The spokeshave is the lowest of the series, and begins with the small inclination of 25° to 30°; and the general angles and purposes of ordinary planes are nearly as follows: *Common pitch*, or 45° from the horizontal line, is used for all the bench-planes for pine and similar soft woods; *York pitch*, or 50° from the horizontal, for the bench-planes for mahogany, wainscot, and hard or stringy woods; *middle pitch*, or 55°, for moulding-planes for pine, and smoothing-planes for mahogany and similar woods; *half-pitch*, or 60°, for moulding-planes for mahogany, and woods difficult to work, of which bird's-eye maple is considered one of the worst.

Boxwood and other close hard woods may be smoothly *scraped*, if not cut, in any direction of the grain, when the angle constituting the pitch entirely disappears; or with a common smoothing-plane, in which the cutter is perpendicular, or even leans slightly forward. This tool is called a *scraping-plane*, and is used for scraping the ivory keys of pianofortes, and works inlaid with ivory, brass, and hard woods; this is quite analogous to the process of turning the hard woods. The cabinet-maker also employs a scraping-plane, with a perpendicular iron, which is grooved on the face, to present a series of fine teeth instead of a continuous edge; this, which is called a *toothing-plane*, is employed for roughing and *scratching* veneers, and the surfaces to which they are to be attached, *to make a tooth* for the better hold of the glue. The smith's plane, for brass, iron, and steel, has likewise a perpendicular cutter, ground to 70° or 80°; it is adjusted by a vertical screw, and the wedge is replaced by an end screw and block.

It is well known that most pieces of wood will plane better from one end than from the other, and when such pieces are turned over they must be changed end for end likewise. The plane working *with the grain* would cut smoothly, as it would rather press down the fibres than otherwise; whereas, *against the grain*, it would meet the fibres cropping out, and be liable to tear them up. The workman will apply the smoothing-plane at various angles across the different parts of such wood according to his judgment; in extreme cases, where the wood is very curly, knotty, and cross-grained, the plane can scarcely be used at all, and such pieces are finished with the steel scraper. This simple tool was originally a piece of broken window-glass, and such it still remains in the hands of some of the gun-stock makers; but as the cabinet-maker requires the rectilinear edge, he employs a thin piece of saw-plate. The edge is first sharpened at right angles upon the oilstone, and it is then mostly burnished, either square or at a small angle, so as to throw up a trifling burr or wire-edge. The scraper is held on the wood at about 60°, and as the minute edge takes a much slighter hold, it may be used where planes cannot be well applied. The scraper does not work so smoothly as a plane in perfect order upon ordinary wood; and as its edge is rougher and less keen, it drags up some of the fibres, and leaves a minute roughness, interspersed with a few longer fibres.

We may plane *across the grain* of hard mahogany and boxwood with comparative facility, as the fibres are packed so closely, like the loose leaves of a book when squeezed in a press, that they may be cut in all directions of the grain with nearly equal facility, both with the flat and moulding planes. But the weaker and more open fibres of pine and other soft woods cannot withstand a cutting edge applied to them *parallel with themselves*, or laterally, as they are torn up, and leave a rough unfin-

ished surface. The joiner uses therefore for soft woods a very keen plane of low pitch, and slides it across obliquely, so as to attack the fibre from one end, and virtually to remove it in the direction of its length; so that the force is divided and applied to each part of the fibre in succession. The moulding-planes cannot be thus used, and all mouldings made in soft wood are consequently always planed lengthwise of the grain, and added as separate pieces. As however many cases occur in carpentry, in which rebates and grooves are required directly across the grain of pine, the obliquity is then given to the *iron*, which is inserted at an angle, as in the skew-rebate and fillister, and the stock of the plane is used in various ways to guide its transit.

Adjustable iron planes have very largely come into use in this country, and in many particulars are more convenient and effective than the wood-stocked tools. Three forms of Bailey's adjustable planes are illustrated in Figs. 3392 to 3396. The plane-iron is fastened down to its bed by means of a lever and a cam operated by a thumb-latch, instead of being wedged in, as in the common bench-plane; and when thus fastened it can be readily set forward or withdrawn as desired by means of the thumb-screw, which is placed under the bed-piece and convenient to the right hand of the workman. Fig. 3392 is a jack and Fig. 3393 a smooth plane. Fig. 3394 represents a circular plane provided with a flexible steel face, which can be adjusted into either convex or concave shape

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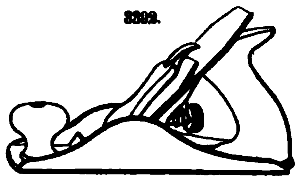

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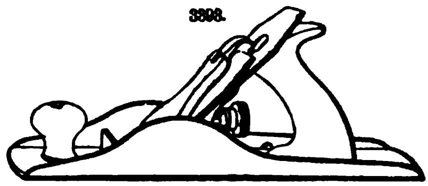

by means of thumb-screws at each end, so that the plane can be used upon curved work. In Figs. 3395 and 3396 are represented two forms of adjustable block-planes. These are adjusted by a screw and lever movement, and the mouth can be opened wide or made close as the nature of the work may require.

Moulding-Planes.—All the planes hitherto considered, whether used parallel with the surfaces, as in straight works, or as tangents to the curves, as in curved works, are applied under precisely the same circumstances as regards the angular relation of the mouth, because the edge of the blade is a right line parallel with the sole of the plane; but when the outline of the blade is curved, some new conditions arise which interfere with the perfect action of the instrument. It is now proposed to examine these conditions in respect to the semicircle, from which the generality of mouldings may be considered to be derived. A small central portion may be considered to be a horizontal line; two other small portions may be considered as parts of vertical dotted lines; and the intermediate parts of the semicircle merge from the horizontal to the vertical line.

The reason why one moulding-plane figured to the half-round cannot, under the usual construction, be made to work the vertical parts of the moulding with the same perfection as the horizontal, exists in the fact that, whereas the ordinary plane-iron presents an angle of some 45° to 60° to the *sole* of

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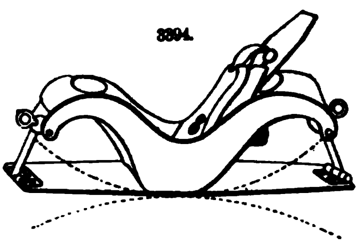

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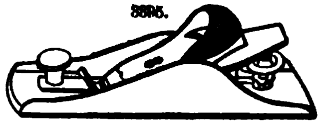

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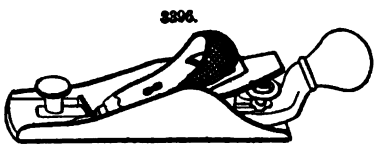
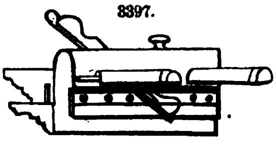


the plane, which part is meant to cut, it presents a right angle to the *side* of the plane, which part is not meant to cut. Thus, if the parts of the iron of the square rebate-plane, which protrude through the sides of the stock, were sharpened ever so keenly, they would only *scrape* and not *cut*, just the same as the scraping-plane with a perpendicular iron. When, however, the rebate-plane is meant to cut at the side, it is called the *side rebate-plane*, and its construction is then just reversed; that is, the iron is inserted perpendicularly to the sole of the plane, but at a horizontal angle or obliquely to the side of the plane, so that the cut is now only on the one side of the plane, which side virtually becomes the sole. A second plane sloped the opposite way is required for the opposite side, or the planes are made in pairs, and are used for the sides of grooves and places inaccessible to the ordinary rebate-plane. The square rebate-plane, if applied all around the semicircle, would be everywhere effective so long as its shaft stood as a radius to the curve, as then the angle of the iron would be in the right direction in each of its temporary situations. But in this mode a plane, to be effective throughout, demands either numerous positions of the plane, or an iron of such a kind as to combine these several positions. Theoretically speaking, therefore, the face of the cutter suitable to working the entire semicircle or bead would become a cone, or like a tube of steel bored with a hole of the same diameter as the bead, turned at one end externally like a cone, and split in two parts.

As all the imperfections in the actions of moulding-planes occur at the vertical parts, there is a general attempt to avoid these difficulties by keeping the mouldings flat, or nearly without vertical lines. For example, concave and convex planes, called *hollows and rounds*, include generally the fifth or sixth, sometimes about the third of the circle; and it is principally in the part between the third and the semicircle that the dragging is found to exist; and therefore, when a large part of the circle is wanted, the plane is applied at two or more positions in succession. In a similar manner large complex mouldings often require to be worked from two or more positions with different planes,

3397.



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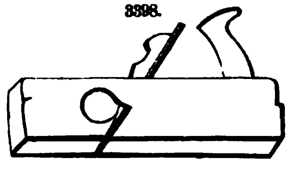

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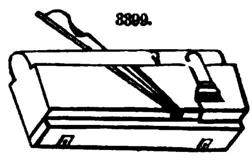

even when none of their parts are undercut, but in which latter case this is of course indispensable. And in nearly all mouldings the plane is not placed perpendicularly to the moulding, but at an angle so as to remove all the nearly vertical parts as far toward the horizontal position as circumstances will admit.

Various forms of wooden moulding-planes are represented in Figs. 3397 to 3401.

Fig. 3402 represents Traut's adjustable plane, which consists of two sections: a main stock, with two bars or arms, and a sliding section having its bottom or face level with that of the main stock.

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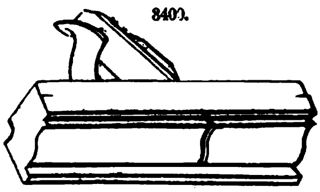

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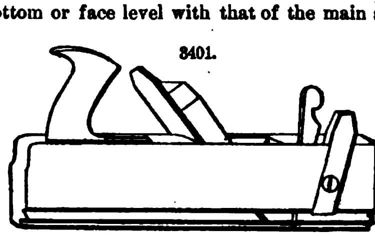

The tool can be used as a dado plane of any width, by inserting the bit into the main stock and bringing the sliding section up to the edge of the bit. The two spurs, one on each section of the plane, are thus brought in front of the edges of the bit. A gauge on the sliding section regulates the depth to which the tool cuts. By attaching a guard-plate to the sliding section the tool is converted into a plough, a fillister, or a matching plane.

Fig. 3403 represents a tonguing and grooving plane. The stock of this tool is made of metal, and it has two cutters fastened into the stock by thumb-screws. The guide or fence, when set as

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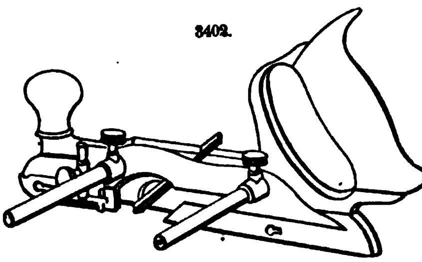
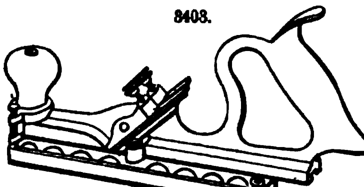


3403.



shown, allows both of the cutters to act; and the cutters being placed at a suitable distance apart, a tonguing plane is made. The guide or fence, which is hung on a pivot at its centre, may be swung around, end for end; thus one of the cutters will be covered, and the guide held in a new position, thereby converting the tool into a grooving-plane. A groove is cut to match the tongue which is made by the other adjustment of the tool.

PLANING MACHINES, METAL. The duty of the metal-planing machine is to produce flat surfaces on metal. Its essential parts are: a traversing table, on which the work is fastened; a bed, to receive said table and guide it in a right line; a cross-slide, to support the slide-rest carrying the tool; standards bolted to the bed and supporting the cross-slide; and the mechanical devices for feeding and regulating purposes.

The principal features of difference, and in most cases of advantage, existing in American machines as compared with those of European makers, are: 1. The employment of two driving-belts, one for the forward and the other for the back movement; 2. Frictional or other devices for actuating feed, independent of the tappets on the carriage, which are employed to shift the belts only; 3. Narrow driving-belts moving at a high speed to facilitate shifting or removing the carriage movement; 4. The arrangement of the gearing in machines having what is called rack movement, so that a large wheel instead of a small pinion is employed as a last mover. Nearly all American makers employ the rack-and-pinion movement; the Sellers machine, which is illustrated farther on, being the most

THE SELLERS PLANING-MACHINE.

conspicuous exception. The gearing, and indeed all parts, have been increased in strength, and the racks and all wheels are in most cases cut. The advantage of two belts instead of one lies in the fact that the extra belt for running back is driven at double the speed of the one for cutting, and takes the place of what may be called the differential gearing which has to be employed on single-belt machines. The difference in the speed of movement is attained by pulleys of different diameter on the countershafts, so that the same pulleys and wheels on the machine answer for the forward and backward movement. In this way the amount of detail is greatly reduced; the weight of the reversible gearing is much less; and as belts are substituted for wheels, there is an absence of that noise and jar which is common to most machines operated with one belt. With two belts, the distance they have to be moved in shifting is only one-half as much as for a single one; that is, with one belt a loose pulley must be introduced between the two driving-pulleys, so that the belt will not lock the machine by being partially on both pulleys at a time. In the case of two belts, they are not shifted simultaneously, but one is moved before the other, so that intermediate loose pulleys are not required.

Frictional Feeding Devices.—There are in use four plans of actuating the feeding-gear of planing machines, as follows: 1. By tappets on the carriage, the reversing and feed movement being accomplished by the first mover; this is the common plan in European practice. 2. By clutches which are engaged and disengaged by positive mechanism. 3. Friction-clutches which maintain a constant torsional strain from right to left throughout the stroke of the machine. 4. Friction-clutches which are engaged and disengaged as soon as the feed-movement is performed, and consume no power when not acting.

The tappet-feed has nearly disappeared in American practice. Planing machines are "handled," as it is termed, mainly by means of the shifting gearing; that is, the table is stopped and started, moved forward or back in setting tools, and so on, by means of a handle operating the belt-shifting eyes. The overhead shaft is seldom stopped for any temporary purpose, and it is easy to see how inconvenient it would be to have the feeding-gear combined with the shifting or reversing movements. (See *Engineering*, xxii.: "Machine Tools at the Centennial Exposition.")

The Sellers Planing Machine, invented by Bodmer in 1841, and subsequently greatly improved by Messrs. William Sellers & Co. of Philadelphia, is chiefly notable for its method of giving motion to the rack. This is imparted by a peculiar form of spiral pinion upon a driving-shaft, which crosses the bed diagonally. This machine is illustrated in a full-page engraving, and in Figs. 3404 to 3411. In addition to the peculiar mechanism above noted, one of its essential features is the employment of slide-rests for operating upon horizontal surfaces, while the ordinary slide-rest is working upon vertical ones. This not only effects a great saving of time, but insures that the finished surfaces shall stand at right angles, independently of any skill in setting the work. The table is furnished with a rack, which receives motion through a peculiar form of spiral pinion, *A* in the plan view, Fig. 3404. This is placed upon a driving-shaft which, as above stated, crosses the bed diagonally and passes out in the rear of the upright, on the side where the workman stands. This shaft is driven from the pulley-shaft by means of the bevel-wheel and pinion *C* and *D*. By this simple driving arrangement, a very smooth and uniform motion is imparted to the table; the pinion has four teeth, and is in fact a short piece of a coarse screw, the position of the teeth upon the same being like the threads of a screw of a steep pitch, and of a like number of threads to that of the teeth in the pinion. The driving-shaft revolves in bearings at both ends of the spiral pinion; these bearings are cast in the bed and connected by a trough surrounding the pinion, which trough is covered by caps under the rack, thus preventing chips and dust from reaching the pinion; the oil placed upon these bearings can escape only into this trough, and furnishes sufficient lubricating material for the pinion and rack. The disposition of the driving-shaft and gearing, which is shown in Figs. 3404 and 3405, may be considered as an improvement over the frequently adopted plan of placing the driving-gear and pulley in front of the uprights on the side of the machine opposite to the attendant; in which

3408.

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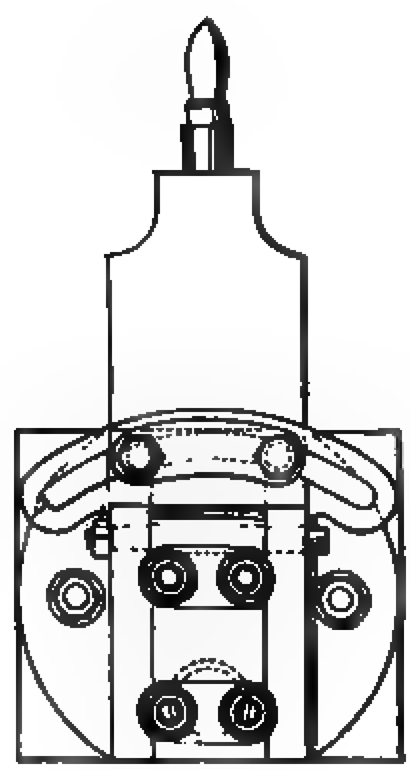
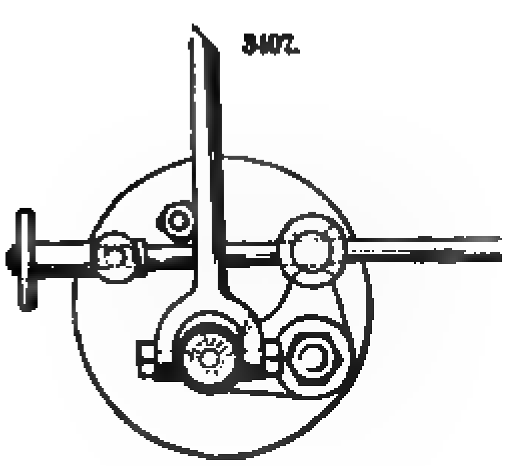


3410.

3407.



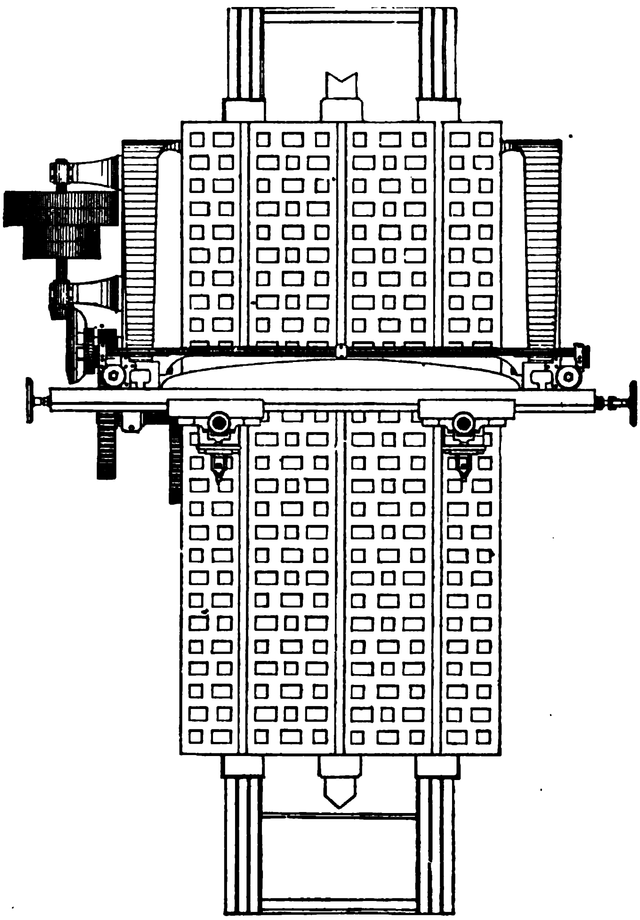
position these parts and the belts are apt to interfere with the planing of pieces overhanging on that side of the table, and are out of reach of the operator. The transmission of motion to the table from a high-speeded belt is accomplished by a single pair of bevels, the larger of which may be easily made of such diameter relative to the pinion as to give the required reduction of speed and transmission of power without the intervention of gearing.

The device for shifting the belt, shown in Fig. 3404, consists of a curiously-shaped lever *L*, vibrating horizontally upon a fulcrum-pin placed between the fulcrums of the two belt-shifters *M* and *N*, the whole being supported upon an upward extension from the cap of the rear bearing of the pulley-shaft. The middle arm is provided on opposite sides with an internal and an external projection or tooth, these teeth meshing with corresponding notches and projections on the respective shifters; the teeth upon the middle lever are relatively so disposed that the motion of one shifter is effected and completed before that of the other is commenced, which arrangement combines, with the least possible lateral motion of the belt in shifting, the important advantage of entirely removing the one belt from the driving-pulley before the other begins to take hold to reverse its motion. The shifting is thus effected with very little power, and the shricking and undue straining of belts avoided. The variation of stroke of the table is obtained by means of the usual adjustable stops on the side of the table, which stops actuate the above-described shifting device by means of a double-armed lever and link connection.

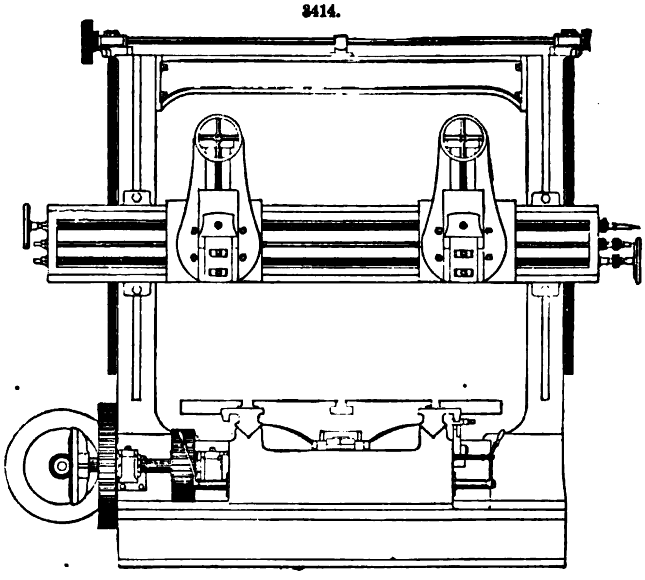
The usual screw and central feed-shaft are provided on the cross-head for transmitting either a horizontal or a vertical feed-motion to the planing tool in either direction. They receive a variable amount of motion for any required feed through a ratchet-wheel, fitted interchangeably to their squared extremities at the front end of the cross-head, where the ratchet-wheel is actuated by the toothed segment shown in Fig. 3405 at *A*. This receives at each end of the stroke the required alternate movement in opposite directions from a crank-disk *B* below, by means of a light vertical feed-rod. As shown in Figs. 3407 and 3408, the crank-pin on the feed-disk below is so arranged that its throw and amount of feed can be conveniently varied and adjusted during the cutting stroke of the table, while the machine is in motion. By means of an ingeniously-contrived double pawl and ratchet-wheel, deriving motion from a pinion on the front end of the pulley-shaft, the crank-plate is at each reversion of the stroke alternately moved a half revolution, and disengaged in either direction; friction is only employed to throw the pawl into gear at each change of motion, whereupon a positive motion of the crank-disk is kept up by the ratchet-wheel until the pawl is disengaged from the teeth of the ratchet-wheel by a positive stop. Figs. 3409, 3410, and 3411 show the construction of the cross-slide and main slide-rest. In nearly all modern planing machines the cutting tool is hung to what is called an apron, so adjusted as to allow the tool to swing loose on the back stroke of the planer-table, but to be held rigidly when cutting. In large planes, when the weight of the tool is great, and in all fine planing, this liberation of the tool is not sufficient of itself. In the present machine arrangements are provided whereby the tool-point can be lifted clear of the work on the back stroke, and dropped into place ready for the

3412.

3413.



3414.



cut after the article to be planed has passed under it. This is effected by lifting the tool, in every position of the slide-rest, from within the cross-head, without interfering with any of the machinery working the feeds, which occupy the centre, about which the adjustable part of the saddle rotates.

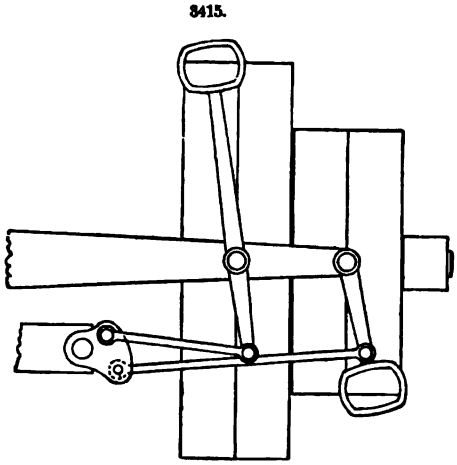
An example of the adaptation of this planer to special uses is represented in Fig. 3412, which is a machine for planing connecting-rods and similar work. It is arranged with two sets of uprights and standards, with a double saddle on each cross-head, carrying four cutting tools as shown, so that it may be employed to plane the four ends of two connecting-rods or four single bars or rods simultaneously. The shortness of the uprights gives great rigidity. The mechanical contrivances for operating the table are the same as already described.

The Freeland Tool Works Planer.—Figs. 3413 and 3414 represent a plan and front elevation of a planing machine constructed by the Freeland Tool Works, New York. This machine, which is 8 ft. in width by 6 ft. in height, is driven by two belts running at right angles to the line of the machine on the pulleys shown —the belt on the large pulleys driving the apparatus while cutting, and the belt on the small pulley driving the reverse way. The power is transmitted through a series of spur- and bevel-gears to the main shaft, which extends across the machine and is firmly supported in substantial bearings. This shaft carries a solid V-pinion about 10 in. in diameter, which gears into a corresponding rack on the bottom of the table, and which, it is said, imparts to the table a motion as steady and free from jar as if driven by a screw. The table is strongly ribbed, and has T-grooves and also square holes for plugs and bolts to secure the work by. The cross-slide has two leaders which are entirely independent of each other, having up, down, and transverse feed-motions, and can

be adjusted to any angle. The feed-motion is communicated by a vertical rod on the side of the machine. The cross-slide is raised or lowered by power. A shaft on top of the cross-brace, having a pulley on one end, gears into the elevating screws and raises or lowers as desired. The beds of these machines are so constructed that, when necessary to accommodate very large work, one of the uprights may be shifted back from its usual position. Fig. 3415 represents the belt-shifting device used in connection with the above-described planer.

Planer-Tools.—The cutting tools used in planers are similar to those employed for turning. (See LATHE-TOOLS, TURNING.) It is easier, however, in planing-tools, to conform to the principle of keeping the cutting edge level with the centre of the tool-steel, as shown in Fig. 3416. The cutting edge of the tool may be dragged much more in planer-work than in lathe-work, because the distance between the cutting edge and the perpendicular line passing through the body of the tool is not of so much consequence. Tools having as much drag as is shown in Fig. 3417 are often employed. In

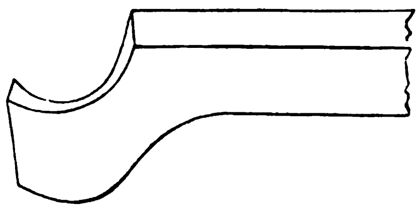
3415.



3416

3417.

3418.



cases where the tool is necessarily weak, and yet must be keen in order to make a clean cut, it is well to give it a front rake by curving the front face as shown on the grooving-tool, Fig. 3418.

Power required for Metal-Planers.—According to Hartig's experiments, the power required to plane away cast iron is found by the formula $P = W\left(.0155 + \frac{1}{11,000\, s}\right)$, in which P represents the power required, W the weight of cast iron removed per hour in pounds, and s the average sectional area of the shavings in square inches.

For planing steel, wrought iron, and gun-metal with cuts of an average character, the same authority gives:

Planing steel	$P = 0.112\ W.$
Planing wrought iron	$P = .052\ W.$
Planing gun-metal	$P = .0127\ W.$

PLANING MACHINES, WOOD. These machines are designed for producing planed surfaces, and for reducing material to any desired dimensions. The methods of feeding the timber and of using the cutters vary with the character of the work to be done. Two principal classes of machines may however be recognized, viz.: those in which the table is moved by the feeding mechanism, and those having a stationary table, the feeding being accomplished by means of rollers. They may also be divided as regards the mode of cutting: one class having a horizontal arm with a cutter fixed in each end of it, the arm revolving over the timber as the latter is carried on the moving table; while in the second class the cutting is performed by a rotating cylinder carrying two or more knives.

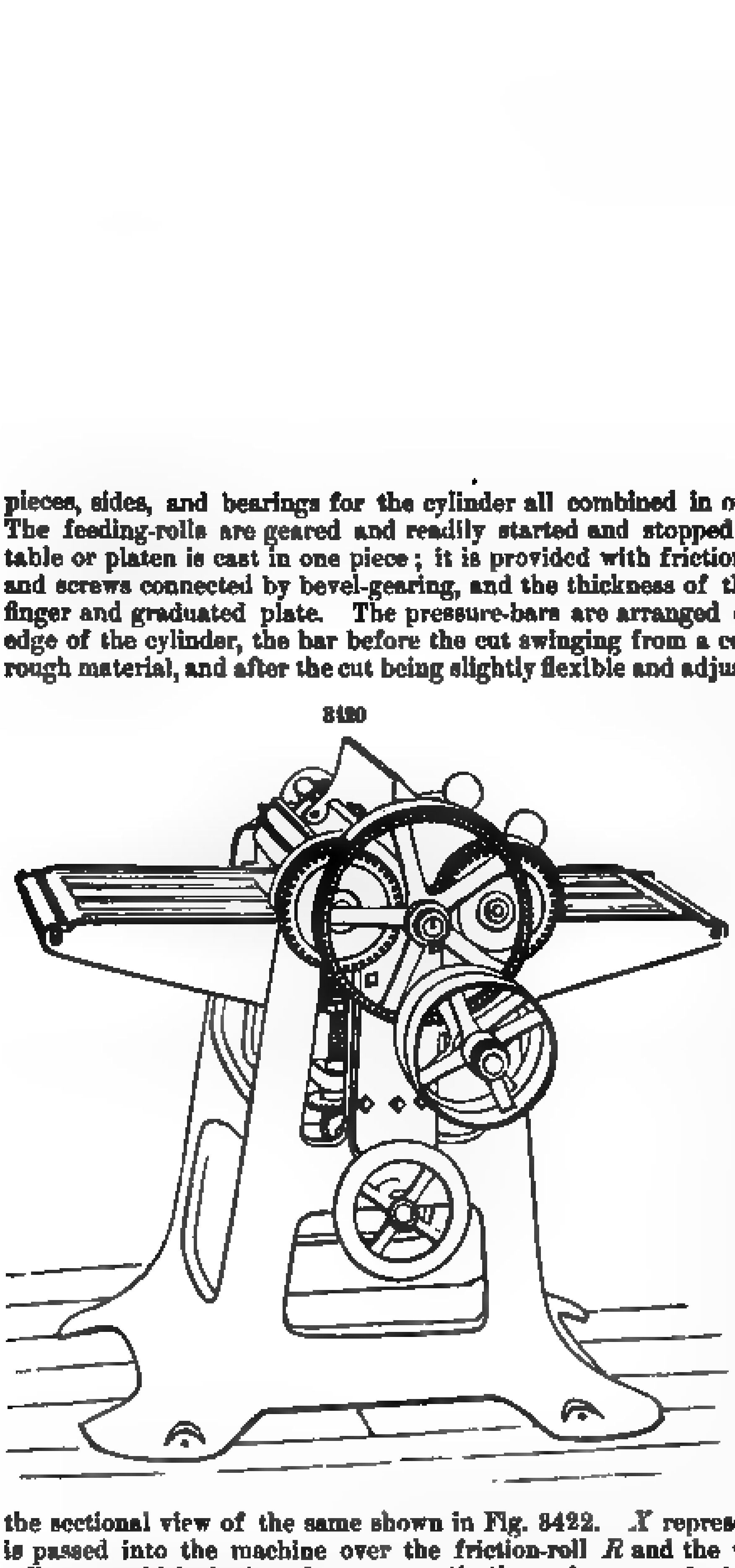
Surface-Planers are those which are primarily intended for smoothing, trimming, or squaring up lumber where it is desirable to have it perfectly out of wind.

The Daniels or traverse planing machine cuts the surface at right angles to the grain of the wood, and belongs to the class in which the cutters are attached to the end of a rotating horizontal arm. An example of an improved machine of this class, devised by Mr. J. Richards, is given in Fig. 3419. The framing is of iron, and the carriage is of similar material with a wooden face. The timber is held to the carriage by the pivoted pawl shown at A and the wedge B. The two cutting tools, C and D, are attached to the horizontally revolving frame E, which is driven by the belt F. The pulley G is made long to accommodate the rise and fall of the cutter-head and frame E, to suit varying thicknesses of timber, the belt always maintaining its horizontal position notwithstanding the vertical height of the pulley G. The pulley G is carried by a vertical frame, which is adjusted for height

by a screw operated through the medium of the hand-wheel *H*, the bevel-gears *I*, and the screw *J*, the last being attached to the frame. The feed provided is a rack and wheel beneath the frame, and is capable of three changes.

Another form of surface-planer is represented in Fig. 3420. This smooths but one side in its operation, the lumber passing between two pairs of rollers under the pressure-bars, and being gauged to an accurate thickness by passing over a smoothly-finished table, which is adjustable to the required thickness. The frame or column of the machine is a continuous casting, having the cross-pieces, sides, and bearings for the cylinder all combined in one piece, forming an inflexible frame. The feeding-rolls are geared and readily started and stopped while the cylinder is revolving. The table or platen is cast in one piece; it is provided with friction-rollers and adjusted by a hand-wheel and screws connected by bevel-gearing, and the thickness of the stuff being planed is indicated by a finger and graduated plate. The pressure-bars are arranged closely to the periphery of the cutting edge of the cylinder, the bar before the cut swinging from a centre as it rises to the thickness of the rough material, and after the cut being slightly flexible and adjustable to the wear of the different parts.

3420



Planers and Matchers. — Among planing machines, the Woodworth or horizontal rotating cylinder planer, with the combinations of pressure-rolls or bars for surface planing and vertical rotary heads for tonguing or matching and grooving, is notable among the first in importance, for its present perfection of construction, and the speed with which it accomplishes its work. An example of a four-roll machine of this type, as manufactured by Messrs. J. A. Fay & Co., is given in Fig. 3421. This will surface up to 24 in. wide and 4 in. thick, and tongue and groove and match up to 14 in. in width. It has four feeding-rolls of large diameter, which will admit stuff 4 in. in thickness. A weighting attachment is provided, which insures uniform pressure on the lumber without regard to the variations in thickness caused by uneven sawing. The cylinder carries three knives, and is fitted with three lips.

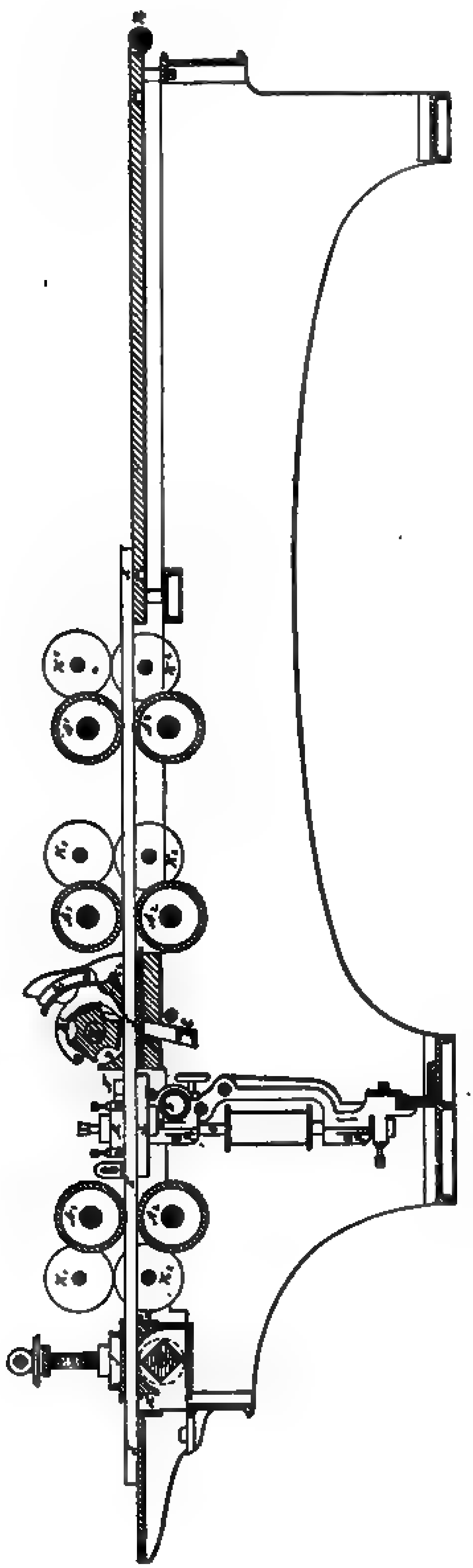
The mode of operation and details of planers of this class will be understood from the full-page plate of the Woods planer and matcher, and the sectional view of the same shown in Fig. 3422. *X* represents a board or piece of wood, which is passed into the machine over the friction-roll *R* and the table T^1. A^2 A^2 are the lower feed-rolls over which the board passes. A^1 A^1 are the upper feed-rolls, which are actuated by expansion gearing (Fig. 3425) in connection with the lower rolls, and which bear upon the surface of the board with an adjustable weighted pressure (shown in Fig. 3424), allowing them to be set at any length for the desired thickness of lumber to be planed. *B* is the top cylinder, carrying three or more cutters and revolving at a speed of 3,000 or 4,000 revolutions per minute. *C* is the yielding-hinged pres-

THE WOODS WOOD-PLANER.

sure-bar, hung on links B', and yielding to any inequalities in the thickness of the unplaned lumber, but holding it firmly by means of the weight C^1, preventing the fibres of the wood from tearing out under the lifting action of the cutters. D is the adjustable yielding pressure-bar, holding the board

3422

3421



in a similar manner after the surface has been planed. G is the under cylinder, which revolves in the opposite direction to the top cylinder, and carries cutters which act upon the under surface of the board, which is held down by the pressure-shoe J. H and H^1 are pressure-bars acting upon the same general principle as C and D.

S is a round bar extending across the machine, upon which slide the matcher-frames, containing spindles O, running in boxes P^1 and P^2, and carrying the head M.

Each machine is provided with two sets of matcher-frames and -heads, which are adjustable across the machine to any desired position, being moved by screws and rods extending to the work-end of the machine, where their position is indicated by scales and pointers and regulated at the will of the operator. Between these matcher-heads passes the board to have its edges tongued and grooved, the chip-breakers N, Figs. 3422 and 3423, being pressed against the edges in close proximity to the line of the cutters, and preventing the splintering or turning out of knots and cross-grained parts.

Fig. 3426 represents a section of the top cylinder with bars, etc. Fig. 3424 shows the manner of connecting the top-cylinder boxes by a yoke running underneath the bed of the machine (see E, Fig. 3422). The boxes on the top cutter-head are tied together by means of a yoke extending across and underneath the bed of the machine, thus giving free access to set, reset, and sharpen the cutters. The object of having the boxes tied together is to keep them in line, and avoid cramping and twisting of journals. Fig. 3425 gives a perspective view of the expansion gearing.

The Hand-feeding Planing Machine, Fig. 3427, is largely employed for the simpler operations of the workshop. The revolving cutters are upon a cutter-bar as shown. The face of the work to be planed is rested upon the face of the table. The table is composed of two parts, one in front and one in the rear of the cutter-bar. The work is placed on the front half of the table, which is adjusted in distance below the top of the circle described by the revolving cutters to regulate the amount of the cut. The back half of the table is stationary, with the plane of its surface in a right line with the top of the circle of motion of the revolving cutters. The object of this arrangement is as follows: The surface of the front table, upon which the work lies previous to its being fed to the cutters, acts as a guide in that operation; but after the work has passed the cutters, the part planed meets the surface of the rear table, which acts as a guide to the planed surface, and prevents the work from rocking upon the table, as it otherwise would do. The gauges shown upon the tables are for guides to rest work against, and serve to regulate the angle at which the surfaces are planed.

Pony-Planer.—The term pony-planer is applied to small planing machines. That shown in Fig. 3428 is expressly designed for fine work. The table raises and lowers to adjust the depth of the cut, and a scale of inches is affixed to the front of the machine to facilitate setting the table for the thickness of the work. It is provided with a belt-tightener, by means of which the belt is made to be tight upon the pulley, causing it to revolve and the machine to start; or, the belt running loose, the machine will stop.

Power required for Wood-Planers.—In planing and moulding machines which are driven at high speeds, a large proportion of the total power is absorbed in driving the machine itself. The formula, according to Hartig, is (empty), $P = \frac{N}{2000}$, in which P represents the total power absorbed, and N the sum of the turns per minute made by the several shafts.

The net power required for moulding and shaping wood is given by the following formulæ:

Pine.	Red Beech, using Cutters.	Red Beech, using Cutting Disks.
$P = .0566 + \frac{.02263}{h}$.	$P = .08695 + \frac{.00731}{h}$.	$P = .0895 + 9.188s$.

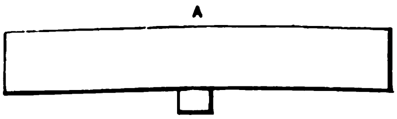
Here P = horse-power required to produce 1 cubic foot of shingles per hour, h = the height of wood cut down to form the moulding in inches, and s = the average sectional area of the shavings in square inches.

PLANOMETER, OR SURFACE-PLATE. This is a truly-surfaced metal plate used as a test for the production of other flat surfaces. By its aid the spring due to the pressure placed upon the work by holding it in the screwed-up jaws of a chuck, or by supporting in any other way with sufficient force to detain it against the pressure of a cutting tool held in a machine, may be detached and removed by subsequent manipulation performed when the surface-plate is at rest and not under such pressure. In surfaces cut by a steel tool there are always marks denoting projections and depressions, which are termed tool-marks; and in surfaces trued by grinding processes, the softer parts of the metal will grind away when the process consists of permitting one metal face to come in contact with the other, with a film of grinding material between. If the plate is operated upon by a revolving wheel, the surface will exhibit innumerable fine scratches, and the harder parts of the metal will become locally heated, causing local expansion; so that it is an excellent wheel-ground surface that will show 5 per cent. of its area in actual contact when placed upon another smooth and truly-surfaced plate. The advantage of ground surfaces is, that the metal may be hardened with a view to resist the abrasion due to being rubbed upon other surfaces to test them. The usual method of producing true plane surfaces is to finish them with a scraper, removing with this tool the parts which testing shows to protrude. The defect of this system is, that the surface formed by scraping consists of innumerable small hills and hollows, the tops of the hills being a true surface; but since the depths of the hollows are variable, the plate soon becomes untrue, because the bearing surface becomes locally increased where the hollows are the shallowest, and the wear on the increased surface is less than at other parts.

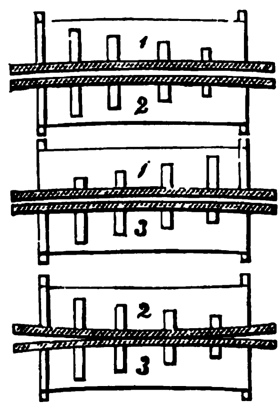
To keep a surface-plate true, it is of the utmost importance that all the area covered by the work shall be in equal contact, because there is much more wear upon the middle than at and toward the edges of the surface. This arises from the practice of workmen to use the middle part of the surface more than the outer portions, especially when the plate is (as frequently is most convenient) balanced upon the work. As an improvement upon the scraping process, filing and polishing have been used to produce plane surfaces of great truth, smoothness, and finish. The rationale of this process is as follows: All metal bodies become deflected by their own weight in sufficient degree to be of practical importance in a surface-plate of even 8 inches square. The amount of the deflection will always depend upon the weight and disposition of the metal and position of its resting points. If we take a bar of steel, say 6 inches square and 36 inches long, and true its surface to a true plane, and then rest it upon a piece of wood placed beneath, midway its length, as in Fig. 3429,

it will deflect in the direction denoted to such a degree that a surface-plate applied to the upper surface will swing upon the centre *A*, and not touch at the ends at all. If, however, we place two pieces of wood beneath the plate, one at each end, contact will take place at the ends and not in the middle, showing deflection in an opposite direction. It becomes necessary then to provide in some way against this deflection. This is usually done as follows: Upon the ribs at the back of the surface-plate, shown in Fig. 3430, there are provided three small projecting lugs or feet *T*, at *A*, *B*, *C*, and upon these lugs the plate rests without rocking, even though the surface on which it stands be an uneven one. Thus, whatever sag or deflection the plate may have will always be in the same direction, and may therefore be allowed for in the truing process. The long ribs upon the back of the plate should be as near as possible in the line of strain between the three feet or lugs, and the

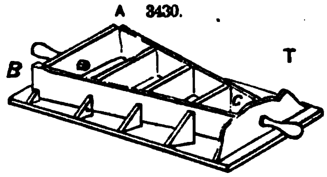
3429.



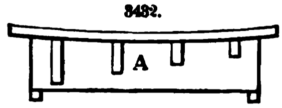
3431.



A 3430.



3432.



cross-ribs should be at equal distances apart. All the ribs should be of a thickness equal to that of the plate itself, so that changes of temperature will cause the ribs and plate to expand or contract equally.

To obtain an original true plate, it is necessary to make three. These are shown in Fig. 3431, and are marked respectively 1, 2, and 3. At the outset a plate is selected which we will term No. 1, and to this a second plate, No. 2, is fitted. Then No. 1 is again employed as a standard whereby to fit No. 3 (not operating upon No. 2 at all). No. 3 is then tested by No. 2, and any error existing between these two is proof of a want of truth in No 1.

Suppose, for example, that, as shown in the figure, No. 1 is hollow; then No. 2, fitted to it, will be rounding. No. 3, also fitted to it, will also be rounding, and the two latter, put together as in the figure, will disagree to twice the amount that No. 1 varies from a true plane. When we have three such surfaces to begin with, it is of great importance, if possible, to select the truest plate of the three to take the position of No. 1, because it is accepted provisionally as a true surface. If, on the contrary, it is the least true of the three, fitting the other two upon it will operate to diminish their truth, and the operation will serve merely to show the want of truth in No. 1. To select the truest plate, the following is an excellent plan: A true straight-edge should be wiped quite clean and placed upon the surface-plate in various positions, as lengthwise, crosswise, and across the corners of the plate. While in each position, take hold of one end, and, without placing any vertical pressure upon it, move it laterally back and forth a little, say about 2 inches, to see where it takes a fulcrum on the surface of the plate. If the centre of its movement is at the centre of the surface-plate, then the surface of the plate is rounded, or highest in the middle; if it moves on the plate first most at one end and then most at the other, the surface is hollow; while if it moves with an irregular and shuffling movement, it denotes that the surface is as true as the straight-edge will test. There is, however, in this method of obtaining a true surface, an error which appears to have been formerly overlooked, because, while the bottom plate has a fixed point to rest upon, the top one has not. For example, in Fig. 3431, where No. 2 is shown resting upon No. 3, it is evident that No. 3 has its own weight and that of No. 2 also tending to deflect it, while No. 2 has also its own weight acting to deflect it in turn to fit No. 3. Suppose, however, that in Fig. 3432 the face of the plate *A* is hollow to the one hundred thousandth of an inch. If another plate be rested upon it, though the latter be absolutely true, yet it will deflect to suit the rounded shape of *A*, and its deflection will be in an exactly opposite direction to the top plate No. 2 shown in Fig. 3431. Hence the direction of the deflection of the top plate varies as its point of hardest contact upon the bottom one varies in location. Were we to stand both plates on edge and true them with the faces standing vertical, neither plate would deflect, because the plane of the surfaces lies parallel to the line of deflection; consequently only the edges of the plate would show the deflection. But in this position we have removed the natural deflection of the surface of the bottom plate. This, even if true when stood on edge, would, when placed upon its feet with its face up, that is, in its natural position, deflect and be hollow. Either of the plates, however, would be true for use with the face downward, that is, as a top plate; and the natural conclusion is as follows: After the three plates are tested interchangeably as described, two of them should be fitted together while tested standing on edge; and as much should be removed from one as from the other during the process. One of these two plates is next fitted to the third,

so that when the last stands upon its feet face upward there will be apparently equal contact between the two all over the surface, and yet when stood upon edge the third plate must appear to be rounding. The third plate must be tested with the other of the two plates which were trued while standing on edge; and when it shows to be rounding with either of the other two plates when tested standing on edge, and yet true when tested as described with regard to Figs. 3431 and 3432, then we have allowed for the deflection, as near as can be, on the bottom or third plate only, when the same is standing upon its feet. It must be borne in mind, however, that this plate, if rested upon another untrue surface, will deflect to a certain amount in conforming to that surface. The new process referred to as adopted by the writer is thus described in the *Scientific American:*

"The planed surfaces of the plates were draw-filed with the finest of files, the bearing-marks being removed with the high spots of the file only. Each file was chalked before being applied to the work, and then a few light strokes of the file were made; after which the teeth of the file were closely examined for the dark spots, which spots indicated which teeth stood the highest. Then only such parts of the file were used as showed the teeth in the middle of the width of the file to be cutting, and which were cutting without any action of the teeth beyond them after passing an area of teeth which were not cutting. By this means the file could be so used that the cutting teeth had contact with the part of the surface requiring to be filed, and yet no other part of the file was doing execution. After having, with a Grobet file, effaced all the marks made by the superfine smooth file, and fitted the plates until the marks showed evenly all over, No. 1 French emery-paper was applied, first lengthwise and then crosswise of the plate. The paper was wrapped, in not more than two folds, around the file, which was done to preserve the edges of the plate from becoming rounded from the action of the emery-paper. The next operation is to move the test plate upon the lower one, backward and forward as well as sidewise, until the marking spots which were at first dark have become bright through abrasion. The emery-papering process is to be continued until the file-marks are effaced all over the plate; while at the same time the test surface-plate marks are distributed evenly all over, that is to say, in spots of about equal area and at equal distances apart."

The next process is to take a piece of Water-of-Ayr stone having a flat surface, and apply it well over the whole surface of the plates, the effect being to remove the fine high spots upon the polished surface, which are plainly seen with a magnifying glass.

"To prevent the emery-paper from cutting in lines, it is moved in circles, say five-eighths of an inch diameter, and pressed firmly upon the plate upon the bright marking spots. After the whole of the marks left by the test have been operated upon in this manner, care being taken to operate more freely on those spots where the test-marks were the heaviest, the process is continued with No. 1 French emery-paper, and subsequently with numbers 00, 000, and 0000, commencing by using the 0 grade upon a file and rubbing it lengthwise and crosswise of the plate, and finishing by the piece of wood and circular motion. A fine film of oil is then to be placed upon the test-plate, which is then freely applied in order to give it a better bearing if possible; and the plates are well rubbed together and interchanged. After each grade of emery-paper the stone must be applied to remove the little hillocks which, though not visible to the naked eye, still show under a lens. The surfaces of the plates should show a polish of equal color all over, and therefore of equal contact; for if the contact is harder in one spot than another, the color of the polish will, if the surfaces are dry and well rubbed together and interchanged, show it plainly. To finish, the plates must be put together, allowing a film of air to be between them, and one plate to, as it were, float upon the other; the top one is then touched sufficiently to set it in motion in all directions; and if any one part of the plate is found to act as a centre of motion more frequently than the others, out of a test of about 20 motions, that part is very lightly touched with worn emery-paper of the 0000 grade."

If the plates are lowered vertically one on to the other, the film of air will remain between them; but if they are placed in contact at the corners only, it becomes very difficult to slide one upon the other. At first, while fitting the plates, it is well to slide one over the other, so that the air will press the two together and make the bearing-marks show more plainly; but the atmospheric pressure will also to some extent warp the plates, making one fit the other, and destroying the test by showing bearing-marks where, but for the atmospheric pressure, the surfaces would not touch. If the plates however are placed vertically, one fairly down upon the other, the test and contact marks are very fine as well as distinct. A pair of plates thus fitted were tested at the Centennial Exhibition, and the result was that, the surfaces being 8 by 12 inches, it required 341¼ lbs. to slide one upon the other. J. R.

PLANTER. See Agricultural Machinery.

PLASTER-CASTING. See Casting.

PLATE-BENDING MACHINE. See Iron-working Machinery.

PLATFORM CAR. See Railway Cars.

PLATING, ARMOR. See Armor.

PLATING, ELECTRO-. See Electro-Metallurgy

PLOUGHS. See Agricultural Machinery.

PLUMBAGO. See Graphite.

PLUMBER-BLOCK. See Journals.

PNEUMATIC CAISSON. See Foundations.

PNEUMATIC DISPATCH. A system of tubes through which packages are driven by the action of compressed air, or by normal atmospheric pressure acting against a vacuum. Pneumatic dispatch has been largely adopted in Great Britain and France, and to a limited degree in this country. In addition to one line of 4½ ft. pneumatic tubes for the transmission of large packages, mail-bags, etc., there is in London an extensive system of small tubes in operation, for the sending of telegraph messages. The small tubes are from 1½ to 2¼ in. in diameter, and are under the control of the Post-Office Department. They are divided into about 20 sections, and their aggregate length at the pres-

ent time (1879) exceeds 17¼ miles. The messages are inclosed in carriers, which are driven through the tubes by an air-exhaust or air-pressure, produced by pumps located at the central station. (See AIR-COMPRESSORS.) Where the length of the tube does not exceed one mile, the carrier goes through in about three minutes; but longer tubes require much more proportionate time. Iron pipes, as well as lead, have been tried; but the result of experience is greatly in favor of lead. No deterioration is experienced in the lead pipes, and they are easy to maintain. With the iron pipes, however, the case is different; oxidation of the iron takes place, and, the interior becoming rough, the carriers are rapidly destroyed. The maintenance of an iron pipe is therefore found to be very expensive.

Provided due care is exercised in the construction of the work, interruptions of the service are of very rare occurrence. When a carrier occasionally sticks fast in the pipe, and cannot be moved either by compressing or exhausting the air, it is necessary to flood the pipe with water, and so force the carrier past the obstruction by an increased pressure. All tubes are now fitted with a small pipe, by which water may be admitted if necessary. The lead tubes are manufactured in as long lengths as possible, the 2¼-inch tubes being in lengths of about 29 ft. Each length is laid in a wooden trough as soon as manufactured, so that it may be handled without fear of bending. A tightly-fitting polished steel mandrel, attached to a strong chain, is then drawn through the entire length of the pipe. This operation insures the pipe being smooth, cylindrical, and uniform throughout. It is necessary that the mandrel should be lubricated with soft soap, so that it may not injure the pipe in passing through it. When laid, the leaden tubes are protected by being inclosed in ordinary cast-iron pipes, so that the sinking of the ground, etc., may not injure them. The process of laying and jointing the tubes is as follows: The leaden tubes, drawn and smoothed as already explained, are delivered from the wooden troughs to the trench prepared to receive them. The iron pipes are then drawn over the lead, leaving enough of the leaden pipe projecting to enable a "plumber's joint" to be made. A strong chain is then passed through the length of tube to be joined on, and a polished iron mandrel, similar to the one before mentioned, being heated and attached to this chain, is pushed half its length into the end of the pipe. The new length of tube is then forced over the projecting end of the mandrel, and the leaden tubes (the ends of which have been already cut flat by an apparatus made for the purpose) then butt perfectly together, and a plumber's joint is made in the usual manner. By this means the tube is perfectly air-tight; and the mandrel keeps the surface of the tube under the joint as smooth as at any other part of its length. After the soldering process has been completed, the mandrel is drawn out by the chain attached to it; the next length is drawn on, and the process is repeated. Where it is necessary to deviate from the straight line, it is essential that the tubes be laid in a circular arc, whose radius shall not be less than 12 ft. The same care is necessary in entering the various stations; otherwise undue friction would arise, and curves would be introduced which might cause the carrier to stick fast.

The form of compressor employed is described under AIR-COMPRESSORS.

Paris has a very elaborate system of pneumatic transmission. The water-pressure in the city mains is used to compress the air. (See AIR-COMPRESSORS.) A full account of the apparatus employed will be found in the *Scientific American Supplement*, i., 376. There are about 13 miles of tubes. The carriages are of two kinds: those which receive the pneumatic pressure and so are forced through the tubes; and those which make up the train drawn by the former, and in which the written messages are directly deposited. The diameter of the tubes is 2.6 in. The speed of a train is some 36 miles per hour, under a total pressure to the tube of from 44 to 45 lbs. About 20 trains of boxes, containing 400 written messages each, can be started per hour. The average cost of water used for compression is about half a mill per dispatch: vacuum, however, being employed without additional cost, a reduction of one-half of this figure follows, so that the water costs 1 cent for every 40 messages.

A pneumatic dispatch system is in use (1879) in the Western Union Telegraph building in New York, and also between that building and the various newspaper offices. The moving of packages in the building is accomplished by a Root's blower. (See BLOWERS.) Packages are sent from all parts of the building to the operating room in the seventh story, but most of them from the receiving room on the ground floor. In the centre of the operating room stands a chest about 5½ ft. high, 18 in. wide, and about 12 ft. long. The upper part of it, about 6 in. deep, forms one chamber, connecting by openings, which may be opened or shut at pleasure, with a dozen or more chambers beneath. A large exhaust-pipe about 8 in. in diameter descends from the middle of the upper chamber to the exhausting engine in the basement. From each receiving desk in the room below a tube about 1½ in. in diameter descends to the floor, and then bending in a gradual curve is carried to the centre of the building, where it ascends vertically with its two dozen fellows to the chest in the operating room. Each compartment in the chest receives two tubes. A cylindrical box about 6 in. long and 1½ in. in diameter, made of stout leather and open at one end, with a flange at one or both ends, as may be preferred, so as nearly to fit the tube, is used as the carrier for the light paper parcel, which is rolled up and held to its place inside the box by its elasticity. The weight of the whole load is but a few ounces, and consequently it needs a propelling force of less than half a pound to the square inch to force it up the tube with considerable velocity. At the orifice in the chamber of the exhausting chest is a bent spring, which arrests the box at its exit, so that it falls with little force into the chamber, at the same time that a lever is moved which closes a galvanic circuit, by which means an alarm is rung to call a messenger. (See the *Scientific American*, xxxii., 223.)

An interesting series of experiments on the pneumatic dispatch are described in a paper "On the Pneumatic Transmission of Telegrams," by Messrs. R. S. Culley and R. Sabine, in the "Transactions of the Institute of Civil Engineers," 1875, abridged in *Scientific American Supplement*, i., 31. The history of pneumatic transmission, illustrations of a large number of devices relating thereto, etc., will be found in a series of articles entitled "Pneumatic Transmission" in *Engineering*, xviii., 293 *et seq.*

PNEUMATIC ELEVATOR. See ELEVATORS.
PNEUMATIC HAMMER. See HAMMERS.
PNEUMATIC LEVER. See ORGANS, PIPE.
PNEUMATIC PILE. See FOUNDATIONS, and PILE-DRIVING MACHINERY.
PNEUMATIC RAILROAD. See RAILROAD, PNEUMATIC.
PNEUMATIC TELEGRAPH. See TELEGRAPH.
PORTABLE RAILROAD. See RAILROADS, PORTABLE.
PORTABLE STEAM-ENGINE. See ENGINES, STEAM, PORTABLE AND SEMI-PORTABLE.

POTTERY-FORMING MACHINERY. The principal machine used in pottery manufacture is the potter's lathe or "throwing-wheel," one of the most ancient mechanical devices in use. Its oldest form was that of an upright shaft about 3 ft. high, which turned in a frame, having a small horizontal wheel at the top, and a larger one at the bottom some 3 or 4 ft. in diameter, and also horizontal, by which it was made to revolve by the action of the workman's foot. A treadle like that of an ordinary turner's lathe is more commonly used, or the form shown in Fig. 3433, which requires the help of an assistant. In large potteries steam-power is employed, a simple clutch mechanism controlled by the workman being used to throw the lathe into or out of gear.

The method of throwing a common stoneware vessel having a circular horizontal section is shown in Fig. 3434. The workman takes a mass of the plastic clay and throws it with a smart blow upon a circular block of gypsum which forms the head of the lathe (*a*), and then presses it firmly with his hands, which he wets in a vessel of water conveniently near, forming it first into a conical shape, represented at *b*, by which means the remaining portions of air are worked out of it, and it is also rendered more plastic. The workman then forces his thumbs into the centre of the mass, holding his fingers on the outside, and gives it the form shown at *c*. Then, by placing one hand upon the inside and the other upon the outside, the forms shown at *d* and *e* are made; and afterward, by means of the simplest tools, made of wood and leather, which are kept wet, the thickness of the article is still further reduced, its general dimensions enlarged, and its shape perfected.

An improvement on hand-moulding for circular work is found in the former, which, attached to a standard, is brought down upon the work from above, as shown in Fig. 3435. The engraving shows the shape of a former used for the exterior of plates. The same device is used to form the interior of cups, etc., the outsides of which are shaped by pressing the clay in a mould.

Faure's Porcelain-Moulding Machines.—An exceedingly ingenious series of moulding machines for porcelain objects has been invented by M. P. Faure of Limoges, France. For plates and saucers he employs a set of three machines. The first is simply a modification of the ordinary potter's lathe, in which the clay is packed in a mould and the interior of the object moulded by a knife or former which is brought down from above. The second machine has a revolving disk, on which the partially formed object is placed. While it is being rotated, a flat disk is brought down upon the work in order to level the edges accurately. The third and most important machine of the series is represented in Figs. 3436 and 3437. The belt from the driving-pulley is taken either to pulley *H* or pulley *G*. A shifter is usually provided (not shown), and connected with the treadle, by which the belt may be shifted to either pulley as desired. Pulley *H* simply rotates the support or head *K*, on which is placed the mould *D*. Pulley *G* also transmits motion by the pulley *I* and belt therefrom

to the pulleys on the vertical worm-shaft shown in Fig. 3437. A separate treadle is provided in some machines for adjusting this belt as desired upon either the fast or loose pulley of the worm-shaft. The worm rotates a cogged wheel, and this transmits motion to the eccentric disks *M* and *L*. The periphery of the inner disk *M* touches a roller, which by means of a rod and other intermediate devices is connected with the profiling knife *B*. Disk *L* also touches a roller which imparts a vibrating motion to the pivoted arm *P*, and this has a projection which enters a slot in a horizontal arm *Q*. The latter is thus caused to move to and fro in a horizontal plane, and so to press another arm on which is a metal former *A* against the surface of the plate, to smooth it, at proper intervals. The arrangement of the disks *L* and *M* is such that the profiling knife is first caused to descend upon and thus give the proper form to the bottom of the plate, and afterward the smoothing or polishing bulb is brought into action. These machines are capable of moulding from 500 to 600 plates per day of 10 hours.

Fig. 3438 represents a machine by the same maker designed for moulding large oval dishes. In this the head *A* is oval, and its edge forms a cam upon which travels the roller *B*. By the revolution of the head this roller is raised and lowered, and in this way the arm *C* is caused to vibrate. The effect of this motion is to bring an inclined former near the extremity of the arm in contact with the side of the inverted dish, while outer formers connected with the arm by a system of levers *D* operate simultaneously on the bottom. It will be seen that the movement of the formers is governed entirely by the cam-rim of the head on which the disk rests.

POUNCING MACHINE. See Hat-making Machinery.

POWDER-MILL. See Explosives.

PRESS, HYDRAULIC. The action of the hydraulic press depends upon the principle that fluids press equally in all directions, and that if the pressure applied to the plunger of the force-pump be multiplied in the ratio of the sectional areas or of the squares of the diameters of the plunger and the ram, the product is the pressure applied to the ram. For the rules governing hydraulic-press construction, see Hydrostatics.

Fig. 3439 represents the side elevation of a small hydraulic press with a hand forcing-pump. *F* is a cylinder of cast iron, fitted with movable piston *D*. Water is conveyed to the cylinder by the tube *b*. The upright bars *A A* are strongly made of wrought iron. *E* is the follower or pressing table. In order to render the piston water-tight, it is surrounded by a collar of pump-leather fitted into a cell made for its reception in the interior of the cylinder. This is so doubled as to resemble a smaller cup within a greater one, and between the folds a copper ring is inserted. In Fig. 3440, *F F* is the cylinder; *D*, the piston; the unshaded parts *o o*, the leather collar, in the folds of which is placed the copper ring, distinctly seen, but not marked in the figure; *m m* is the metal ring by which the leather collar is retained in its place; *n n*, the thin plate of copper or other metal fitted to the top of the cylinder, between which and the plate *m m* is seen the soft packing of tow which serves to oil the piston and prevent its derangement. According to experiments made by Mr. John Hick, M. P., the friction of the leather collar increases directly with the pressure and with the diameter; and it is independent of the depth of the collar. The friction is equivalent to 1 per cent. of the pressure for a 4-inch ram, ½ per cent. for an 8-inch ram, and ¼ per cent. for a 16-inch ram. The following formula is deduced: Leather new or badly lubricated, $6 = .0471\, d\, p$, and leather in good condition, $f = .0814\, d\, p$; in which $f =$ the total frictional resistance of a leather collar, $d =$ diameter of the ram in inches, and $p =$ the pressure in pounds per square inch.

3439.

3440.

In order to understand the operation of the press, we must conceive the piston *D*, Fig. 3439, as being at its lowest possible position in the cylinder, and the body or substance to be pressed placed upon the crown or pressing-table *E*; then it is manifest that if water be forced along the tube *b* by means of the forcing-pump, it will enter the chamber of the cylinder *F* immediately beneath the piston *D*, and cause it to rise a distance proportioned to the quantity of fluid that has been injected, and with a force determinable by the ratio between the square of the diameter of the cylinder and that of the forcing-pump. The piston, thus ascending, carries its crown, and consequently the load, along with it; and by repeating the operation, more water is injected, and the piston continues to ascend, till the body comes into contact with the head *B* of the frame, when the pressure begins. By continuing the process, the pressure may be carried to any extent at pleasure within safe limits. When the press has performed its office, and it becomes necessary to relieve the action, the discharging-valve, placed in the furniture of the forcing pump, must be opened, which will allow the water to escape out of the cylinder and return to the cistern, while the table and piston, by means of their own weight, return to their original position.

Taylor's Direct-acting Steam and Hydraulic Press.—Fig. 3441 is a side elevation and Fig. 3442 a sectional plan view of the steam and hydraulic cylinders of Taylor's press, which is designed more especially for compressing cotton-bales. The mode of working is as follows: Before beginning to press the bales, steam from the boiler is admitted into the cylinder *B* by opening the valve *P*. This drives the piston *F* and consequently the plunger *H* to the other or front end of the cylinder, thus

raising the press-rams S S through a corresponding portion of their stroke. This is however only a preliminary stroke, for the purpose of heating the cylinder and enabling the steam just delivered at the back of the piston F to be transferred to the other side of it. This is done by closing the pressure-valve P, and opening the equilibrium-valve Q, through which the steam in the cylinder passes into the pipe M; as it cannot get past the closed inlet-valve T on the cylinder A, it passes up the pipe M to the front side of the piston F, which, partly by its own weight and partly by the pressure due to the press-rams S S and their platen, transmitted through the water in the press-cylinders and pipes, returns to the outer end of the cylinder B. Supposing that the bale of cotton to be compressed is now placed in the press,

3441.

T falls by its own weight; and the valve P being opened, fresh steam from the boiler is admitted to the back of the piston F, driving forward the smaller plunger H, any steam on the front side of this piston being exhausted direct into the atmosphere. The increased pressure due to the smaller plunger closes the clack O (which acts as an intermediate check-valve between the two water-pressures); and thus the finishing pressure is given to the bale, or whatever may be in the press, and is maintained for any desired length of time. This volume of steam last admitted, after being transferred to the front side of the piston F, furnishes the steam required for the earlier part of the next stroke of the press, which, as before, is done by the plunger G. The press-rams being now raised to the height required, the equilibrium-valve Q is opened, and the steam at the back of the piston F is

transferred to the front of it, as before described; the exhaust-valve U and the clack-valve O are also opened at the same time, and the steam in the cylinder A is exhausted; the pistons E and F are then in position ready to commence the next pressing operation. The valves are all worked by one man by means of rocking shafts, and suitable means are provided to prevent the pistons E and F from coming into contact with the ends of their cylinders.

The following are the dimensions, etc., of a cotton-press constructed on this principle: There are two cylinders with the rams S S working upward; these raise a cross-head, to which are attached

strong wrought-iron links carrying the following table or platen, as shown in Fig. 3441; the casting on which the cylinders rest forms the top platen, and the water being forced into the cylinders raises the lower platen, on which is placed the cotton-bale, and compresses the latter to the required density. The steam-cylinders are each 56 in. in diameter; the pressure of steam used is 80 lbs. per sq. in.; the area of each piston being 2,463 sq. in., this multiplied by 80 gives 197,040 lbs. total pressure on one piston. The smaller hydraulic plunger is 9¾ in. diameter or 74.66 sq. in. area; and $\frac{197,040}{74.66}$ = 2,640 lbs. per sq. in. as the pressure on this plunger. The cotton-press itself has two rams, each 22 in. diameter, the collective area of which is 760 sq. in.; and 760 sq. in. × 2,640 lbs. per sq. in. = 2,006,400 lbs. or 895 tons total pressure on the bale, with 80 lbs. per sq. in. steam-pressure in the boiler. With a pressure of 3 lbs. per sq. in. in the steam-cylinder, all the weight and friction of parts are overcome; and since each pound per square inch of steam-pressure represents a total pressure of 2,006,400 ÷ 80 = 25,080 lbs. on the press-rams, the total frictional resistances amount to only 75,240 lbs., or say 35 tons approximately. Deducting this from the total pressure of 895 tons, there remains 860 tons total effective pressure on the bale. It must not be forgotten, moreover, that a part of the dead weight raised is utilized in returning the pistons and rams after each pressing operation is over.

The makers of these presses guarantee to press at the rate of 75 bales per hour, on a consumption of fuel not exceeding one ton to 300 bales, or 7.46 lbs. of coal per bale; frequently in practice the consumption does not exceed 6 lbs. per bale. Firms using this press at Mobile, Augusta, Charleston, etc., have, we are informed, turned out bales at the rate of 80 per hour.

Presses for Printed Paper.—After sheets of paper come from the printing-press they are strongly marked with type indentations, in order to remove which pressing is necessary. This was originally done by dividing a volume into parcels of a few sheets, and these, being held flat on a stone, were beaten with a heavy hammer until the desired smoothness was obtained. This laborious operation was superseded by the "hot press." This mode required very strong, powerful screw-presses. Fullers or glazed boards were placed alternately between the sheets. Iron plates were then heated and laid between each 20 or 30 sheets, and the whole was pressed together by a lever and windlass. The objections to this process are the damaging of the color of the paper by heat and the danger of the ink running. Cold pressing as now commonly practised is done in a powerful hydraulic or iron-screw press, glazed boards only being placed between the sheets. Efforts have been made to smooth the sheets by placing them between pieces of leather or tin plates and passing them between rollers. This process is slow, although it is said to render the paper smoother than the above-noted methods of direct pressing.

An ingenious form of press specially devised for printed paper has been invented by Mr. J. W. Jones, Superintendent of Public Printing of the State of Pennsylvania, which is used in the Government printing office at Washington, and which under conditions of actual test is reported to have given notably successful results. It is a hydraulic press disposed in a new way, as shown in Fig. 3443. The pressure is applied by two hydraulic pumps provided with an adjustable automatic safety-valve. The ram travels its entire stroke in 30 seconds. About 500 folded sheets are put into the trough of the machine, and boards are placed at each end to secure even pressure. The ram is then caused to act, and while the bundle is under pressure it is secured by strong cords. It is then removed and set aside. This operation can be done regularly every three or five minutes, so that the machine will dry-press from 6,000 to 7,500 sheets per hour. The bundles are kept tied for from 12 to 24 hours, in which period the indentations will be removed, and the sheets rendered smooth and free from set-off.

PRESSES. Presses for various purposes will be found described under the following headings: brick-press, Brick-making Machinery; cloth-press, Cloth finishing Machinery; coining-press, Coining Machinery; cheese-press, Dairy Apparatus; cartridge-press, Cartridge-making Machinery; drop-press, Hammers, Power; gunpowder-press, Explosives; nut-press, Forging Machines. See also special articles under Press, Hydraulic, and Presses, Printing.

Cotton-Presses.—Cotton-pressing by the hydraulic press is described under Press, Hydraulic. The methods of compressing cotton by steam, tying, handling, and shipment of bales, are described under Steam Compression of Cotton.

Drawing Presses are used for cutting and drawing articles of sheet metal. Fig. 3444 represents an improved form of press of this description made by the Ferracute Machine Company of Bridgeton, N. J., adapted for a great variety of seamless tinware, such as cups, dippers, wash-bowls, etc., up to 4 in. deep by 16 in. in diameter. The press is built on the bottom-slide principle. It has a

heavy base casting, supporting the shafts, gearing, fly-wheel, etc., and the four columns which form the bearings for the slides. The outer slide, to which is bolted the blank-holder, is driven up by the

3444.

two outer cams a certain distance, adjustable by the four rods with double nuts, and remains stationary while the inner slide, with punch attached, ascends a greater distance (adjustable by a screw with lock-nut on plunger), carrying the punch up into the upper die, thus drawing the sheet-metal blank from between the surfaces of blank-holder and upper die, and forming it to any shape required for pans, basins, cups, etc. The cams are made very wide, and of such a shape that they drive the slides up very slowly while the work is being done, and allow them to return quickly, thus economizing power and time. The height of this press above the floor is 5½ ft., and its total weight 7,000 lbs. The stroke of the bed is: outer slide, 4½ in.; inner slide or plunger, 9 in.

Fig. 3445 represents a *changeable foot-press* built by the same company. The main frame *B* is wide and deep, of a section giving uniform strength throughout; the widths at all points, counting from the front of the bed back and up to the main fulcrum, being derived from parabolas of the requisite form. The changeable legs *F* give a combined upright and inclined press. The slide-bar *K* is of dovetail section, and is driven by means of the lever *D*, which has a friction-roller set in it for a bearing in the slide-bar. The motion is communicated from the foot-treadle to the lever *D* by the pitman *H*. This pitman has a swivel in it consisting of a hand-wheel and nut, so that, without using a wrench, a delicate adjustment may be given to the slide-bar. A treadle-stop *J*, with a hand-nut attached, controls the distance the treadle moves. The stop *J*, and end of treadle that strikes the floor, are provided with rubber bumpers to prevent noise and jar. The press is fitted with patent die-clamps by which dies can be rapidly set

without bolts or wrenches. They are made to adjust sidewise to suit different widths of dies. A hollow bolt or sleeve is secured in a slot through the bed and bolster plate by a large nut underneath, and on its lower end has a screw (of, for instance, 9 threads per inch), on which runs a hand-wheel. Through this sleeve slides a hardened steel bolt with a hooked head at the top, and at the bottom a screw thread (of, for instance, 10 per inch), running on which is a flanged nut. The steel bolts being swung around with their heads over the die and allowed to drop upon it, the wheels are run down until they strike the flanged nuts. The latter then revolve with them by friction of the surfaces, but do not descend quite so fast, owing to the varying pitch of screws. This differential action tightens the die with great force. The wheels leave the nuts and run up rapidly on their single screws when it is wished to relieve the pressure.

The engraving shows the press in inclined position. It can be changed to upright position by disconnecting the lever *D* from the pitman *H*, and revolving it in its socket until the set-screw comes underneath the ball, and then shifting the legs so that the bolt at *F* goes into the hole *G*, and the bolt at *G* will come into the hole *C*, and the lever *D* is then to be reconnected to the pitman *H*. Most of the work made in a press is cut and formed in the dies complete at one stroke, and rises between the upper and lower dies. In upright presses the pieces formed have to be removed laterally by the hand of the operator; but the inclined press has an advantage in the fact that the work as soon as formed (by the force of gravity) slides off the lower die, through the hole in the back of the press, and down the chute *E*, into any proper receptacle.

A form of power-press by the same makers as the foregoing is represented in Fig. 3446. It is used for cutting and forming sheet-metal work. The fly-wheel runs as a loose pulley on the shaft, and the motion is communicated to the shaft by means of a sliding steel clutch which is operated by a touch of the toe-treadle, and is so arranged that the shaft makes but one revolution and stops positively with its eccentric and pitman at top of its stroke, unless the treadle is held down by means of the lock, when continuous strokes are made. The slide-bar is of dovetail shape, very wide, and extends up back of the shaft, giving a long bearing. It receives its motion from the shaft by means of a pitman provided with a ball-and-socket joint at the lower end, and with thread and lock-nut at the upper end for adjusting the height of the bar above the bed or table of the press. Sliding and revolving steel clamps are set in the bed to hold the bolster-plate or lower dies securely in position, and the upper die is fastened to a bushing in the bar which can be revolved so that the upper and lower dies (if of irregular shapes) will coincide. An automatic spring-brake bearing on a cylindrical projection on the shaft controls the exact stoppage of the bar at the top of its stroke.

Fig. 3447 represents a form of drawing press manufactured by Messrs. Bliss & Williams of Brooklyn, N. Y. In this machine the lower die is made of the same diameter as the size of the blanks for the ware to be stamped. By this means the operator is enabled, by bringing the edge of the blank fair with the circumference of the die, to set the blanks true in the machine without requiring to use any great care in adjusting on the die. The blank-holder *J* descends and holds the blank in position, while the drawing punch *H* forces it the necessary distance into the lower die *K*. In the middle of the latter is a table supported by a spiral spring, the duty of which is to force the ware out of the lower die as the blank-holder rises.

Fig. 3448 represents a power seaming press manufactured by Milligan, Sayce & Co. of Newark. It is designed to make an impermeable seam without the aid of solder. Its method of operation is as follows: Upon a cylindrical mandrel are two adjustable gauges, in which the pieces of tin to be seamed are placed. An upper die descending stamps the metal into the form shown in Fig. 3449. This die is made in two parts, one within the other. The inner die recedes, leaving the outer one holding the metal firmly in position. A die from the inside of the mandrel now ascends, and forces the metal into the upper die, the appearance now being as in Fig. 3450. The two dies now approach each other firmly, stamping the metal together as in Fig. 3451, completing the seam.

Baling Presses.—Fig. 3452 represents a form of lever-press used for baling hay, cotton, etc., by hand-power. The material to be compressed is placed in the box *V*, and the platen to which the chain-wheels *A* are attached is raised by drawing up the chain by means of the chain-wheel *I*, which is rotated by the ratchet-wheel *H*, which is attached to it and operated by the lever *D* carrying the pawl *G*. The bale is discharged at the side of the box after throwing back the hooks *M* and removing the cross-bar *N*.

3452.

The Boomer & Boschert press is represented in Fig. 3453. This machine is made to operate by hand or steam power, as illustrated. The platen is carried downward by straightening the two oppositely disposed toggle-joints by means of a screw, as shown. As the two parts of each toggle approach a vertical position, the pressure on the bale increases and the motion of the platen diminishes.

The Bookbinders' Embossing and Stamping Press, Fig. 3454, is used for embossing the covers of books. The designs, or dies, usually of brass, are cemented to an iron plate held by jaws or clamps up against a platen, which is heated by steam or gas. The cover is laid on the bed and brought up against the brass die by a toggle-joint, which is straightened by a cam or crank. The impression is regulated by a hand-wheel oper-

2454.

ating a wedge beneath the toggle. This press is usually run at a speed of 25 revolutions to the minute.

The Book-pressing or Smashing Machine is on the same plan as the above, but is used for compressing the unbound books or folded sheets.

PRESSES, PRINTING. These may be divided into three well-defined classes, which came successively into existence, each later class being in point of rapid working greatly in advance of its predecessors.

I. Platen Presses.—The first type of this class, used by all the early masters of the art, from Gutenberg and Caxton down to our own Franklin, whose simple press was shown in the Centennial Exhibition, had a flat "type-bed" and "form," and, suspended immediately above or opposite to the bed, a "platen," or impression-plate, also flat, but of only half the area of the bed, so that two impressions were required for each side of a sheet. Most of the parts of this press were made of wood, the bed being a stone. The substitution of iron for nearly the whole, in the beginning of the present century, permitted the platen to be made as large as the form, requiring but one pull to a side; and, with other improvements, this is still the "hand-press" of the present day. The type being placed upon the bed, properly inked, and the paper spread over it, the "impression" is given by pressing the platen forcibly against it. This was at first accomplished by means of a screw, and afterward by a combination of levers.

The Washington Press.—Fig. 3455 is the modern representative of the oldest type of the platen press. *a*, is the iron framework; *b*, the bed on which the types are placed; *c*, one of the two grooved rails on which the bed slides forward to receive the impression; *d*, the "rounce" or crank, which moves the bed to and fro; *e*, the platen; *f*, the bar, which, by a combination of levers, depresses the platen; *g*, the spiral spring, which raises the platen after impression; *h*, the "tympan," a sheet of thin cotton cloth, stretched on a frame of wood; *i*, the "frisket," a mask of perforated paper

stretched on a frame of thin iron, to prevent soiling of the paper by ink; *k*, the inking roller and its frame. Preparatory to taking an impression, the paper is laid on the tympan, the frisket is folded down upon it, and then the tympan upon the bed, by which the paper is placed on the inked types; the bed is then moved under the platen, and the impression given by pulling the bar-handle. The ink was formerly dabbed on with two soft, leather-covered pads, which one pressman kept working together to distribute the ink evenly, while the other worked the press. Rollers, made of several thicknesses of cloth wound round a wooden cylinder and covered with soft leather, were afterward introduced. These were finally superseded by rollers of composition. One person was still required to apply the ink, and another to work the press; but later a self-inking apparatus was invented, by which the pressman, in running in the bed, raises a weight which, in its descent, draws the roller over the form. With this, one man, though with considerable exertion, may thus do the work of two. A good pressman will work off about 2,000 impressions per day, but cannot well run a press large enough to work paper of more than eight octavo pages.

The Treadle Job Press is represented in Fig. 3456. The ink-distributing apparatus is composed of cylinders *E*, *D*, *F*, etc. The distributing roller *E*, and another roller with a lateral motion, work in combination, and cause the ink to be carried diagonally in directions continually crossing and recrossing each other, insuring great uniformity of distribution. By simple devices the inking of the form may be repeated once or more before each impression, and the pressure can be accurately and quickly adjusted. The platen has a short rest when receiving the paper, then swings up parallel with the form, against which it is thus drawn to give the impression. The paper is laid on and taken off by hand. The press may be driven by power. This press has lately been adapted to the printing of paper on one side automatically from rolls. After the impression the sheet is cut off and drops on a table.

3456.

The Adams Power Press, introduced in 1830, and still largely employed for book-printing, represents the most improved style of press of the first class. It is now manufactured exclusively by R. Hoe & Co. of New York. The bed carrying the form is moved up against the stationary platen by a toggle motion. The inking-roller carriage, provided with sheet-grippers, travels between the bed and platen, inking the form, and carrying in the sheet (previously fed to it by hand) over the form to receive the impression, and then bringing it back to be blown by the bellows into tapes, and carried by these over the sheet-flyer. This flyer is composed of a series of light wooden strips or fingers, attached to a shaft which makes a half turn, and in so doing lifts the sheet off the tapes and lays it, printed side up, on a table.

II. Cylinder Presses.—The second class of printing machines originated, as did the first, in Germany. The type-bed is flat, but, instead of receiving the impression from a platen, it passes back-

3457.

ward and forward under a revolving cylinder, which rolls in concert with it. This press first became widely known through its adoption in 1814 by the London *Times*, and, with many improvements and modifications, it now does the great bulk of the printing of the world. Cylinder presses have been greatly improved during the past few years, and those of American manufacture now take rank among the finest specimens of machinery in the world.

The Drum-Cylinder Press, Fig. 3457, is a well-known type of this class. It has a large cylinder, which revolves continuously, having one side of a smaller radius than the other, to permit the safe return of the bed The momentum of the bed is checked at each end of its stroke by air or metallic springs, which also serve by their recoil to help to start it in the opposite direction. The register is sufficiently accurate for good color-work. The paper is fed from a table, seized by the fingers of the revolving cylinder, carried around on its surface against the form, brought up and transferred to the fingers of the delivery cylinder, which in turn send it on cords down in front of the flyer to be deposited, printed side up, on the fly-table.

Fig. 3458 represents a two-roller cylinder press constructed by Messrs. C. Potter, Jr., & Co., of

3458.

New York. The sheets are delivered without tapes around the cylinder, and a novel positive slider-motion prevents the sliders from working to either end of the track. Hinged caps to the distributor-bearings admit of the ready removal of the distributor and form rollers, and the fountain is operated from the cylinder-shaft, instead of from the type-bed.

The Campbell Four-Roller Cylinder Press.—This press is so far automatic when in operation, that the sheet itself by a delicate mechanism causes the impression; therefore it does not print on the

9461.

THE COTTRELL AND BABCOCK CYLINDER PRINTING PRESS.

tympan, and the press will not operate the fly (which is in front of the cylinder), unless the sheet is fed. If the sheet is not fed accurately, it is thrown down by the fly so as to be distinguished from those perfectly printed. This press is without springs or tapes. It has one or two ink-fountains and two or four rollers, as desired. The distribution is under the control of the pressman, who may cause the form to be rolled once or oftener for each impression, the movement of the fly being then automatically arrested.

Presses for the finest wood-cut printing are usually made with small cylinders, which stand still during the return of the bed; one side of the cylinder being flat to avoid contact with the type. (See Fig. 3459.) These machines, termed stop-cylinder presses, are constructed with great nicety, and are used for the very finest work.

3460.

Presses for newspaper printing have usually small cylinders which revolve continuously, rising in their bearings after each impression to allow the bed to run back. (See Fig. 3460.) Some have two cylinders, so arranged as either to print a sheet at each stroke of the bed, or to print each sheet on both sides. But all the machines of this second class are in principle like the first one mentioned, having a flat bed moving backward and forward, carrying the form of type first under rollers which ink it, and then under the impression-cylinder, where it prints the sheet, which is delivered at the rear of the press.

The Cottrell & Babcock Cylinder Press.—Fig. 3461 represents the four-roller two-revolution press constructed by Messrs. Cottrell & Babcock of New York, which is designed more especially

3462. 3463.

3464. 3465.

for fine printing. The general construction of the machine is that outlined above, and its peculiar features are illustrated in detail in Figs. 3462 to 3465. The most important of these are some of the attachments to the air-spring, which reduces the wear due to the stopping and reversing of the reciprocating bed. To overcome the momentum of the bed of a 30 × 52-inch cylinder press of this

construction with a full form of type, running at the rate of 1,800 impressions per hour, about 3,500 lbs. of resistance is required on each centre. By the use of gauges the amount of spring employed is ascertained, and when the bed is passing the centre the plunger can be adjusted to the spring-pressure requisite for the speed at which the press is running. The bed is provided with two cylinders to engage with the plungers, seen at the end of the frame; and the hollow rods of these plungers are connected by a pipe running along the lower part of the frame, which pipe is opened or closed by the valve of the governor, shown through the opening in the framework. Fig. 3462 is a longitudinal section of the same. Fig. 3463 is a cross-section of the piston A, springs allowing the outside packing to contract and expand. The governing device, whereby when the press is in motion the spring is automatically applied, and the resistance augmented as the speed progresses, or *vice versa*, is represented in Fig. 3464. The device is here attached to the connecting-pipe with a plug-valve, which it operates, and two spring-gauges to indicate the amount of condensation in the cylinders. The valve is shut by the motion of the press when running at speed, and is open when the press is at rest. This enables the press to be started at any point without helping it over the centres by hand. The spring-gauges indicate the pressure in the air-cylinders; and, as this is determined by setting the plungers backward and forward on their rods, the amount of spring is easily adjusted to the speed of the press. A device is also used for controlling the momentum of the cylinder, and thus preventing the back-lash due to the tendency of the cylinder toward greater velocity than that of the reciprocating bed. The attachment simply keeps the gears up to the work-side of the teeth, and so harmonizes the motion of the two parts. Fig. 3465 represents the hinged roller-frame. When the frame is open the vibrators are arranged so that they can be taken out without unscrewing the boxes, and are locked in place by a downward movement of the frame.

The Hoe Two-Revolution Four-Roller Press, Fig. 3466, is especially adapted for illustrated newspaper, book, and similar work. The improvements recently made enable this press to run at a high rate of speed with smooth and noiseless motion. The moving parts are under the complete control of the

3466.

operator, and the entire arrangement affords ready access to all its parts, and a quick adjustment when a change of form or size of sheet is required. Different-sized sheets can also be printed and delivered with equal facility. The delivery mechanism takes the printed sheets from the main cylinder without the aid of cords or tapes, delivering them in front of the fly, which deposits them, printed side up, on the fly-board. An examination of the cut explains its simplicity of construction, while its capacity is unequaled by any other press of its class. It is provided with air-springs of improved design, and all the latest improvements and conveniences.

The Potter Lithographic Press, Fig. 3467, is also a stop-cylinder press. The traveling bed on which the stone rests is drawn under the cylinder by a crank and connecting-rod from the end of the frame below, and the cylinder, after being thrown into gear, is rotated at the same time. At the end of the stroke the cylinder goes out of gear, and remains stationary during the return of the bed, the latter passing under the cylinder, but not coming in contact with it. The inking of the stone is effected by parallel rollers, which receive their ink from a table at the end of the bed. The automatic dampening arrangement is at the back of the cylinder. It consists of a shallow trough in which revolves a wooden roller; an absorbent roller distributes the water to other rollers which pass over the surface of the stone, depositing the amount of moisture required.

In all steam lithographic presses the pressure is made by the cylinder, whereas in hand-presses it is made by a scraper.

The Hoe Lithographic Press, Fig. 3468, is designed for the finest quality of lithographic work. The bed is drawn backward and forward by a crank, and engages with the cylinder when moving forward, but leaves it standing when moving back. It has an adjustable platform on which the stone rests. The form-rollers (from four to eight) are driven by the contact of the steel distributing rollers above them, the surface of which runs always at the same speed as the printing surface. The bed may, if desired, pass two or more times backward and forward under the inking rollers before

taking an impression, and a friction-clamp causes the impression-cylinder when running at high speed to stop without tremble. The stone is damped automatically by rollers which receive water from a fountain—the amount being adjustable according to the size of the stone. The sheets are

3467

seized by the grippers, and the points withdrawn just before the cylinder starts, this insuring perfect register. The printed sheets are taken direct from the cylinder by the fingers of the delivery cylinder, and piled, printed side up, on the fly-table.

3468.

The Hoe Stop-Cylinder Press, for the finest wood-cut and letter-press work, is very similar to the above. It has from four to eight inking rollers.

Flat-Bed Perfecting Presses are those which print on both sides sheets fed by hand. They are provided with a second impression-cylinder and form, and the sheet, after receiving an impression on the first cylinder, is automatically transferred to the second impression-cylinder and printed on its reverse side. They are sometimes so arranged that an "offset-sheet" may be fed in with the fresh paper, to receive the offset from the first freshly printed side and prevent the soiling of the blanket and paper.

III. Rotary Presses.—The third class of printing machines comprises those in which not only the impression-surface but the type-form also is made cylindrical, and revolves in contact with the impression-cylinder.

The Hoe Type-Revolving Press is the principal example of one division of this class of machines. The forms are locked up in curved beds, which when secured in place in the machine form a segment of the main type-cylinder, but occupy only a part of its periphery, the remainder being used as an ink-distributing surface. Around the central cylinder are clustered as many impression-cylinders and sets of inking rollers as can be conveniently arranged. The sheets are fed by hand to these impression-cylinders, which seize and bring them in contact with the form; they are then conveyed by tapes to the sheet-flyer which accompanies each impression-cylinder, and piled open or flat on

THE HOE PRINTING-PRESS.

the receiving boards. This press is used for printing newspapers of large circulation, and in its most improved form is capable of working off 20,000 impressions an hour.

The Web Perfecting Press.—This type of the third class of printing presses takes its name from its printing upon a "web" or roll of paper. Its distinguishing feature consists in the combination of two pairs of type and impression cylinders, so arranged that impressions may be made in continuity on the long web of paper, which in its course through the press presents each surface respectively to a type-cylinder, and is therefore printed on both sides at one operation. The invention of the flexible *papier-maché* matrix, although of great value in the rapid production of stereotype plates, and largely used in combination with the rotary press last mentioned, proved of vital importance to the success of the web perfecting press, as it enables the production of cylindrical stereotype plates (in facsimile of the "make-up") which completely cover the type-cylinder—a requisite not readily attained with the original type. The web, after printing, is severed into sheets at one operation. A machine of this kind was invented by the well-known philanthropist, Sir Rowland Hill, who patented it in England in 1835, though indeed the broad idea of printing from cylinders is found in Nicholson's English patent of 1790. Neither, however, produced a successful machine.

The web perfecting press of the present day is shown in one of its simplest forms (the delivery mechanism being omitted), in outline, in Fig. 3469, which will illustrate with sufficient accuracy the main printing features of presses of this class. They may be of sufficient width to print two papers

3469.

abreast, and, the motion of nearly all the parts being rotary, they run at an astonishingly high speed. The paper from the roll A, controlled by suitable tension devices, passes under the equalizing roller E to the impression-cylinder F, and upon the surface of this to the first type-cylinder G, by which one side is printed. Thence the paper goes over the second impression-cylinder H, which is two or more times the diameter of F, to the second type-cylinder, which prints the second side. Shifting tympan-cloths are stretched around impression-cylinder H, which is of large diameter to prevent the offset from falling constantly upon the same place. The fountain L, and the distributing and form rollers N, O, P, Q, R, S, T, U, V, are the usual devices for inking the form. The paper when printed passes to the cutting cylinders, one of which, K, carries a projecting serrated knife, while its companion, J, has a corresponding groove along its length. Elastic surfaces hold the paper during the cut, while notches in the knife leave unsevered portions, by which the sheets still hold together and are led to the delivery mechanism. The invention of this delivering machinery, to dispose of the printed paper with sufficient accuracy and rapidity to make the press of practical value, is of recent date, and the relative success of the different manufacturers in this respect is indicated by the speed at which their presses run.

The Bullock Press (an American invention) has its printing cylinders arranged substantially in the order shown in Fig. 3469. It delivers its papers flat, gripper-belts carrying the sheets from the cutting cylinders to the flyers, which strike them down singly upon the tables; there being two complete sets of tables, belts, and flyers, arranged one above the other. This press prints at a speed of 9,000 quarto (eight-page) or 18,000 folio (four-page) papers an hour.

The Walter Press (English), named after the proprietor of the London *Times*, prints that journal and also the *New York Times*. This press has a series of damping rollers, through which the paper passes from its roll to the printing cylinders. These are arranged one above the other, the first

type-cylinder being uppermost, the two impression-cylinders between, and the second type-cylinder at the bottom. The paper, when printed on both sides, is by cutting cylinders severed into sheets, which are carried by tapes to the top of the delivery mechanism, whence they descend perpendicularly, to be laid singly upon tables by a flyer which vibrates alternately to the right and left. The *New York Times*, a quarto paper, is printed at the rate of 9,000 sheets an hour.

The Victory Press (English), with its folding machine, is represented in Fig. 3470. The roll is placed on brackets at one end, and the paper is led over two wetting boxes; then, after being printed as usual on both sides, over two hot copper cylinders; and then travels on tapes to the cutting and folding cylinders. The first fold is given by a blunt knife, fixed transversely across the peripheries of the wheels, which forces the paper into the gripper of a second cylinder, by which the doubled

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paper is carried over half a revolution, when a serrated steel knife cuts off the first perfect printed sheet from the web. A second blunt knife forces the doubled paper into the grippers of the third folding cylinder; and the newspaper, thus twice folded, is carried round by grippers to a vibrating frame, which delivers each alternate sheet to a pair of cross-folding rollers. It is then forced, by means of a steel knife raising the paper, between the tapes which traverse up each side of the delivery end of the frame, carrying each alternate sheet to the second pair of rollers, when a second cross-folding knife comes sharply down and forces the middle of the paper in between two rollers, under which the delivery apparatus swings. The delivery consists of a frame which swings backward and forward like a pendulum, the paper traveling down between the tapes while it is going one way, and being thrown out upon the table as it comes back. This machine, it is stated, prints and folds 9,000 perfect copies of an eight-page newspaper 50 inches square, or 18,000 copies of a four-page paper, an hour.

The Scott Rotary Web Press, manufactured by Messrs. C. Potter, Jr., & Co., of New York, is represented in outline in Fig. 3471, and in perspective in Fig. 3472. A double-width press of this kind has printed and folded with two folds 30,000 small folio newspapers an hour. The roll of paper is placed so that it slides into position easily without rising up. The folding is done by rotary creasers; as the knife revolves and cuts off the sheets, the creasers revolve and fold them. The sheets are printed, cut, and receive the primary folds without the use of tapes or belts.

In the sectional view, *A* represents the first distributing cylinder; *a*, *a*, *a*, vibrating distributing rollers; *B*, fountain roller; *b*, ductor roller; *C*, *C'*, transmitting gears; *D*, first plate or type cylinder; *d*, *d*, *d*, form-inking rollers; *E*, first impression-cylinder; *e*, *e*, web-supporting rollers; *e'*, smooth-

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THE SCOTT ROTARY WEB PRINTING PRESS.

ing bar; *F*, second impression-cylinder, of large size, and provided with a set-off sheet; *G*, second plate or type cylinder; *g*, *g*, *g*, form-inking rollers; *H*, second distributing cylinder; *h*, *h*, *h*, vibrating distributing rollers; *I*, fountain rollers; *i*, ductor roller; *J*, driving gear; *K*, male cutting and folding cylinder; *k*, folding creaser; *L*, female cutting and folding cylinder; *l*, first folding grippers, which are held in position by means of springs and opened by a crank on end of rod; *l'*, second folding grippers; *M*, folding cylinder; *m*, folding creaser; *m'*, transferring grippers; *N*, carrying roller; *n*, cords passing round the female cylinder; *O*, carrying tapes; *P*, *P'*, rollers; *Q*, packer; *R*, folding cylinder; *S*, folding creaser; *T*, receiving board; *U*, paper-roll stand; *V*, wheel and screw to regulate margin; *W*, web or roll of paper.

The operation of the machine is as follows: The web of paper passes over the impression-cylinder, down between the cutting and folding cylinders *K* and *L*, where it is severed by the knife *k*, the leading end of the web passing around the cylinder *K* by the action of the atmosphere against the surface. When the cylinders have made a half revolution, the centre margin of the printed paper comes opposite the creaser *k'*, which forces it into a groove in the cylinder *L*, where it is held by the grippers *l*, which were previously opened (by means of a cam) to receive it. The double edge of the sheet then passes around cylinder *L* to cylinder *M*, to which it is transferred by the grippers *m'*, and drawn around until the creaser *m* forces it into the bite of the grippers *l'*. The twice-folded sheet then passes up between *L* and *N*, the rear end being severed from the web as before mentioned, and is led off of *L* by cords *n*, thence between the tapes *O* and between the rollers *P*, *P'*, and in front of the packer *Q*, which delivers each paper on the receiving board *T*. When more than two folds are desired, the guide-fingers *p* are pressed down below the level of the tapes *O*, and the papers allowed to pass on to the folding cylinder *R*, where they receive another fold by the creaser *S*, or as many more folds as may be desired, and are delivered on the receiving board in the same manner as previously described, but in the opposite direction, as shown.

The stereotyping machinery which accompanies this press is claimed by its makers to be in advance of anything previously produced; by its use a page can be stereotyped and the press running in ten minutes after the form is made up.

The Ingram Press (English), Fig. 3473, is adapted to wood-cuts as well as letter-press. It prints the *Illustrated London News* at the rate of 6,500 an hour, delivering the papers either flat or folded. It has two folding machines, each receiving alternate sheets, consisting of vibrating blades with the customary rollers. A blast of air aids in laying flat sheets. One peculiarity of the machine is its calendering cylinders to remove the indentations of the first impression, and leave a smooth surface for the second, which contains the illustrations. A machine of this kind in the Paris Exposition of 1878 had printing and impression cylinders all of equal size, and printed at each revolution three whole sheets of the *Illustrated London News*.

The Hoe Perfecting Presses.—These feed and print in the usual manner, but the delivery of the printed sheets is effected in a variety of ways, and by mechanisms differing widely from each other. Two styles of this class of Hoe press are shown in the Plate and Fig. 3474. Those intervening differ according as the paper is a folio or quarto, as it is to be printed single or double, and as the columns run around the type-cylinder or lengthwise of it. It is also sometimes necessary to print a four- or an eight-page paper on the same press, and at the same time to be able to enlarge the paper by one or more columns, which necessarily brings the columns and the centre margin, or line of first fold, parallel with the run of the paper. Sometimes a quarto paper must be cut at the head and pasted down the back, and often the folded papers must be delivered ready counted for the carriers in lots of ten or more. The several resulting mechanisms are as follows:

To deliver sheets flat—i. e., not folded—a collecting cylinder gathers a specific number of sheets one upon the other on its surface, then sends them together to the sheet-flyer. By this arrangement

3474.

the fly works slowly and easily, while the sheets run at full speed in a continuous stream from the printing cylinders to the revolving collector. This enables the maximum rate of printing to be utilized. To print and deliver folded a four-page paper (with columns around the cylinder), the sheets, partially severed, are conveyed between tapes to faster-running rollers, which part them from the main web. They then pass to two folders, each receiving alternate sheets and consisting of the customary blades and rollers combined with carrying tapes. If the paper is a quarto (eight pages), to be cut at the top, pasted and folded, a collecting cylinder interposed between the cutting cylinders and the folder gathers two four-page sheets one upon the other (one of the sheets by the usual devices having been pasted), and sends them on together to the folder. Or the sheets may pass alternately over a long and a short path, so as finally to come together one above the other, over folding rollers between which they are forced by the usual blade. When the columns run across the line of travel, the collecting cylinder may carry within its periphery a swinging folding blade, which, when sheets to the desired number are gathered on the cylinder, is swung out, forcing the sheets between folding rollers, whence they pass to other folders as before described. It will be understood that the collecting cylinder may form a part of any "delivery," either for the purpose described or for delivering the folded sheets in packs ready counted. This class of mechanism is that represented in the Plate.

Fig. 3474 represents the other style of the Hoe perfecting press. The delivery mechanism here shown dispenses entirely with the tapes and reciprocating folding blades, is positive in all its movements, and is therefore a most important invention. The cutting cylinders are provided, the one with a fixed folding blade extending along its length, the other with a corresponding groove provided with nipping jaws, which seize the sheet along its centre margin and carry it onward, causing the forward half to lie back over the rear portion, which has in the mean time been severed from the web. The sheet may be thus delivered with one fold, or a second fold may be given by a swinging folding blade carried in the periphery of this second cylinder, and the sheet sent between rollers to another set of folding cylinders arranged at right angles with the first, to be further folded crosswise. A double-width press would thus print and deliver two papers abreast, the printed web being of course slit while passing through the machine. When it is desired to print and deliver a double or quarto sheet by the same press, it is accomplished by the "sheet-turner," Fig. 3475, a very ingenious but simple device, by which one half of the printed web is turned over on the other half; the cutting and folding cylinders will then act upon the doubled web, and quarto (eight-paged) papers will be thus produced, folded as desired. A machine of this kind was put in operation in the *Boston Herald* press-rooms in 1875, delivering papers in folio form for dailies and in quarto form for weeklies, pasted, cut open at the head, and folded for the mail, at a high speed. The compactness and simplicity of this machine distinguish it from others of this class.

Another kind of Hoe web perfecting press consists, in its simplest form, of a single type and impression cylinder, and a single inking apparatus. Each cylinder is in length twice the width of the web of paper to be printed, and the forms for the two sides of the web are placed one at either end of the type-cylinder. The paper from its roll passes between these cylinders, and, after being printed on one side by the form at one end of the type-cylinder, is passed around the sheet-turner (Fig. 3475), by which it is turned over and also transferred to the other end of the type-cylinder, where it is printed on its second side. It is then cut into sheets, which may be delivered open or folded, as described above. By placing one or more impression-cylinders around the type-cylinder, with inking and web-turning apparatus for each, two or more rolls of paper may be printed at the same time, thus increasing the production of the machine.

3475.

The Hoe Type Perfecting Web Press, adapted to print from the type itself, consists in the combination of their well-known type-revolving cylinder with inking and impression cylinders, and a modification of the sheet-turner so arranged as to turn the paper in the path of its travel, and thus present both its sides successively to the type-cylinder, so that two or more rolls of paper may be printed simultaneously.

This machine prints from type on both sides of a endless sheet or roll of paper, cuts it into sheets, and delivers them open or folded, as may be desired, at one operation. In its general construction and appearance it is not unlike the type-revolving press. The forms of type are locked up in curved beds or "turtles," and if the machine is for printing an eight-page paper, the four outside forms are placed on the large central type cylinder in a group, with their heads toward each other, and the four inside forms are similarly placed on the type-cylinder, diametrically opposite to them. As these forms occupy only about one half of the circumference of the type-cylinder, the space between the groups is used as an ink-distributing surface, and receives ink from an inking apparatus in the usual manner. The type-cylinder is surrounded by and connects with several smaller impression cylinders, alongside of each of which is placed a set of form-inking rollers, which, as the type-cylinder revolves, receives ink from the inking surface, and in turn inks the forms. If the machine prints from a single roll of paper there will be four impression cylinders; if it prints from two rolls, eight impression cylinders are used, and double the quantity of work is produced. The paper is taken from rolls, which are about three feet in diameter, and contain about four and one half miles of paper, or from 6,000 to 7,000 sheets each. The webs of paper, having been previously dampened, pass between the type-cylinder and

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R. HOE & COMPANY'S TYPE-REVOLVING WEB PERFECTING PRESS.

the first two impression cylinders, and receive two consecutive impressions from the outside and inside forms alternately, and in this order its first side is printed. The web next runs through a simple but ingenious device called a "turner," consisting of two stationary bars and a roller, which operate to turn the paper over. The web then passes between the type-cylinder and the next two impression cylinders, and has its second side printed from the same forms in precisely the same manner and order as was the first side, and it is so timed, when presented to these last impression cylinders, that the outside pages will be printed on their opposite side from the inside forms, and the inside pages will in like manner be printed from the outside forms. Thus, the web of paper as it issues from the printing cylinder will be composed alternately of two consecutive sheets, having the outside pages uppermost, and two consecutive sheets having the inside pages uppermost. The webs of paper now pass on to the cutting cylinders at each extremity of the press, which at each revolution cut off a sheet. These sheets enter a series of tapes, which conduct them to "collecting cylinders," which carry the first sheet around with it, and at its next revolution receive a second sheet upon the first one. This pair of sheets, which we will suppose to be the two having the outside pages uppermost, are, by means of a device termed a "switch," directed off from such collecting cylinder into a set of tapes, which conduct them to a sheet flier, which piles them upon a table. The two next sheets, which will be the ones with their inside pages uppermost, are now collected one upon the other, and directed to a second sheet flier; thus all the sheets with their outside pages uppermost are laid in one pile, and all those with their inside pages uppermost are laid in another pile. In printing four-page sheets, the two outside forms are placed side by side on the type-cylinder, with their heads, say to the front side of the press, and the inside forms are put on the cylinder diametrically opposite, but with their heads to the front of the press, for, if the heads of these forms were all placed to one side of the press, it is apparent that the paper, when turned over and printed on both sides, would have the heads of the pages on its two sides pointing in opposite directions, but with the forms properly placed, and the outside pages "backed" on the inside forms, and *vice versa*, the sheet will be correctly printed, and each pair of sheets will be collected and piled on the proper tables. This machine is constructed to print from two rolls of paper at once. There are four impression cylinders placed at each side of the type-cylinder, and a roll of paper is printed, cut, and delivered at each side of the machine simultaneously at a speed of 16,000 to 22,000 perfect papers per hour.

It will be understood that all the various "deliveries" described above are capable of being adapted to deliver a paper of two or more leaves pasted together on their centre margins and laid down flat, or with any desired number of folds, and in many cases may deliver two varieties of folded papers at the same time, as, for instance, folded for mail and also for carriers. The pasting devices are of various kinds suited to the form of the paper and the kind of delivery.

The important matter of delivering a supplement with the main sheet is accomplished by the following machines and methods, which are secured by patents to R. Hoe & Co.:

The Hoe Perfecting Supplement Press is of sufficient width to print the supplement abreast of the regular sheet from the same roll of paper, which is of course the width of a supplement wider than the regular main sheet. In this case the supplement portion of the paper is slit longitudinally and laid by the sheet-turner upon the main portion, and the paper thus doubled and pasted, if desired, enters the delivery mechanism, by which the sheets are cut and folded as previously described, each sheet containing its supplement.

The Hoe Double-Web Perfecting Press is of usual width, but provided with a third type-cylinder, which is readily brought into action when a supplement is required, and is also arranged to revolve at half or equal speed with the main type-cylinders, as a whole or half-sheet supplement requires. The supplement in this case is printed from a second roll of paper, which is printed on one side on one end of the third type-cylinder, then, as it travels around the turner, it is reversed and transferred to the other end half of the type-cylinder and backed, when it with the main printed web enters the delivery mechanism, which cuts and folds the main and supplement sheets together, and delivers the same as single products or signatures.

By another method, the supplements are printed in advance in a continuous web, which is rewound into rolls by simple devices driven by the press. When the regular sheet is to be printed, a printed supplement roll is placed in position; the forward end of such supplement web is properly entered between feeding cylinders, which are provided with devices by which a supplement is severed from the web and associated with a main sheet, with which it is folded and delivered simultaneously. These supplement devices are driven at the proper speed, dependent upon the size of the supplement; the accuracy of the operation being insured by devices which automatically regulate the position of the relative sheets while the press is running at full speed.

The Hoe Pamphlet Press, by which pamphlets are printed and completed from paper in rolls at an astonishingly high rate of speed, consists in brief of a combination of the mechanism above described, in which case one of the rolls of paper may be of a different color and serve as the pamphlet cover, being so placed as to lie on the outside of the other printed webs.

PRINTING, CALICO. See CALICO-PRINTING.

PRINTING TELEGRAPH. See TELEGRAPH.

PROFILING MACHINE. This tool is employed to cut pieces of metal to the exact form and size of a given pattern, and is mainly used in the production of irregular forms, for which purpose its accuracy renders it specially useful. In Fig. 3481 is shown this machine as constructed by Pratt & Whitney of Hartford, Conn. *A* is the bed, carrying the cross-slide *B*, and supporting the work-table and the belt-pulley *D*. Upon *B* is the sliding head carrying the vertical spindles *E*, which are revolved by belt connection from the pulley *D* to the pulleys *G* and *H*, the latter being fast upon the vertical spindles, which carry in their lower ends revolving cutting tools similar in form to reamers. To one side of the spindle *H*, in the clip *I*, is fastened a guide-pin. In the ordinary form

of machine the manipulation is as follows: A templet of the size and form of the work to be produced is bolted to the table, and the piece of metal to form the work is also bolted to the table, the distance between the work and the templet being the distance from centre to centre of the spindle and guide-pin. By moving the table and the slide carrying the spindle, the guide-pin is traversed around the edge of the templet, and the revolving cutter cuts the work to the size and shape of the pattern, because the motion of the cutter around the work is identical with that of the guide-pin around the pattern.

It is usual to file up the pattern as nearly as possible to the required shape, and then to use the first piece cut by the revolving cutter as a pattern, removing it from its position beneath the revolving cutter to that beneath the guide-pin. In the machine illustrated this is obviated by the introduction of the spindle *J*. The provisional pattern is chucked to the table beneath the spindle *G*, and the piece of metal to form the permanent pattern is placed beneath the spindle *J*. The guide-pin is placed in *G* and the revolving cutter in *J*; and the permanent pattern is thus cut, chucked in the position it is intended permanently to occupy, thus avoiding any error which might arise from moving the pattern from one position to the other. The spindle *J* is then thrown out of gear and the guide-pin inserted in it, the revolving cutter changed to the spindle *G*, and the work proceeds, the pattern never having been changed from the position in which it was cut. It is obvious that if the gearing by which the table and cross-slide are operated has any back-lash or lost motion in it, the motion of these parts will be inaccurate in turning corners; and to avoid this, double gears and independent adjusting screws are employed in the gearing governing their movements, so that by adjusting these double gearing and adjusting screws the lost motion may be taken up (one gear-wheel or one screw being placed in advance of the other to the amount of the lost motion). The perimeter of the revolving cutter acts upon the edges, while its radial end-face acts upon the horizontally lying surfaces of the work. J. R.

PROJECTILES. Projectiles may be classified according to their form, as spherical and elongated; according to their structure and mode of operation, as solid, hollow, and case-shot. Spherical projectiles are commonly used in smooth-bore guns. Elongated projectiles are employed in all modern forms of rifled cannon. The best length for elongated projectiles, for accurate firing with any ordinary twist, has been found to be from 2 to 3 calibres. The shape is that of a cylinder surmounted by a spiral head, or figure generated by the revolution of a spiral or pointed arch about its axis. Expanding projectiles are so constructed as to take the grooves of the rifling by the expansion of a ring of soft material, due to the pressure of gases in its rear. To this class belong Parrott's projectile, which has a cast-iron body and a brass ring cast into a rabbet formed around its base; Dahlgren's, which is of cylindro-conical shape, and has a leaden cup attached to its base; Shenkle's, cast iron, surrounded by a papier-maché ring; and Hotchkiss's, made in three portions, which, being forced together as the gun is fired, cause the expansion of a leaden ring. Projectiles covered with lead, copper, or brass, or provided with studs to enter the grooves of the rifles, are also used. Shells are hollow projectiles made of cast iron and filled with gunpowder, which is ignited by a fuse at the required moment, causing the envelope to fly into fragments. The thickness of metal in a spherical shell is about one-sixth the diameter, and the weight of the shell is about three-fourths that of solid

shot of the same calibre. Case-shot are a collection of small projectiles inclosed in a case or envelope, which is intended to be broken in the piece by the shock of the discharge, or at any point of its flight by a charge of powder inclosed within it. The three principal kinds of case-shot are grape, canister, and shrapnel. Grape-shot is composed of a number of small shot arranged around a spindle on an iron disk, and held in place by a canvas cover. Canister is a metallic cylinder about one

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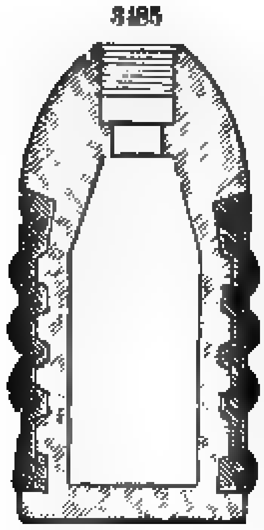
3483.

3484.

calibre in length, filled with balls and closed at both ends with wooden or metal disks. Shrapnel is a thin-sided shell in which are placed, besides the bursting-charge of powder, a number of small balls imbedded in sulphur.

Examples of some of the various forms of projectiles are given in Figs. 3482 to 3485. Fig. 3482, which represents the Palliser shell, shows the general shape of all elongated projectiles. This is constructed of chilled iron. The shot of similar form is cored out. Fig. 3483 is the Boxer shrapnel. Fig. 3484 is the Hotchkiss shell. Fig. 3485 is an example of a shell coated with lead or other soft metal

3485



Deviation of Projectiles.—The causes of deviation of all projectiles, independent of inaccuracy in pointing and variable position of the gun-carriage, are the wind, variable projectile force of the powder used, and rotation of the earth, which last tends to move the projectile with the same velocity in the same direction as the point upon the surface from which the gun is fired. The chief causes of deviation in spherical projectiles are windage, or difference between diameter of projectile and that of the bore; imperfect form or roughness of their surface; and eccentricities arising from their not being homogeneous. Elongated conoidal-headed projectiles, fired from rifled guns giving a right-handed rotation, always deviate or "drift" to the right; if the rotation be left-handed, the deviation is to the left. With flat-headed projectiles their deviations are reversed.

Effects of Projectiles on Armor.—There are two systems of destroying armor by projectiles, by punching and by racking. Under the first system projectiles are driven completely through the armor, with the object of taking effect on whatever may be behind it. On the second system the armor itself is broken up and destroyed, leaving the structure it covered exposed to the effects of subsequent fire. The former system originally obtained entirely in England; the latter principally in this country, as being suited to heavy guns discharging projectiles of great mass with low velocity. Until very recently all English investigations have been upon punching projectiles and wrought-iron armor. The introduction of steel plating, and the disintegrating effects upon it of heavy projectiles, have again brought the racking system into prominence. The various forms of armor and the effects of projectiles on the same are described under ARMOR.

In order to estimate the probable effect of a projectile upon an object, it is necessary to calculate the total energy in the projectile at the moment of impact. This is given in the formula $\frac{W V^2}{2g}$, in which $W =$ weight of projectile, $V =$ final velocity, and $g =$ gravity (32.2 ft.). The punching effects

of projectiles are usually compared by calculating what is termed the energy per inch of circumference in foot-tons, which is found by dividing the total energy by the number of inches on the circumference of the projectile, or $\frac{W V^2}{2g \times \pi R}$, where R = radius of the projectile. Where projectiles are made of the same material and are similar in shape, their penetration into unbacked plates is nearly in proportion to their living force, or their weight multiplied by the square of the velocity of impact. The resistance which an unbacked plate offers to penetration is nearly in proportion to the square of its thickness, provided this thickness be confined within ordinary limits. In the case of oblique plates, the penetration diminishes nearly with the sine of the angle of incidence.

For weights of projectiles for modern guns, see articles under ORDNANCE. For bullet-making, see CARTRIDGE-MAKING MACHINERY. See also works for reference under ORDNANCE. A valuable discussion on the resistance of modern armor appears in a paper by Captain C. O. Browne, R. A., in *Engineering*, xxvii., 69.

PROPELLERS, SCREW. See SCREW-PROPELLERS.

PUDDLING. See IRON-MAKING PROCESSES—PUDDLING.

PUGGING. See CARPENTRY.

PULLEYS. For designing of pulleys, see BELTS. Belt-pulleys, once made entirely of wood, subsequently of wood with iron centres, are now almost universally of cast iron with turned faces (ground, filed, or polished) and carefully balanced. The S arms, once considered indispensable for strength, have, in the foundries of the best makers, given way entirely to straight arms. Pulleys thus made, as shown in Fig. 3486, require less metal, are stronger and more elegant, and, with proper selection of iron and precautions in cooling, no trouble will result from shrinkage or strains; provided, of course, that the hubs, arms, and rim be of the correct relative proportions. In this country, pulleys, except for special cases or when of very large size, are cast in one piece. Large pulleys made in two or more parts are cast in segments, which are planed and fitted together and secured by bolts, and the pulley then bored and turned on its face. Pulleys up to about 6 ft. in diameter, however, are frequently cast in one piece, but having lugs on the rim and the exterior of the hub, separated by cored staves, so that the pulley may readily be broken in two by wedges and then reunited with rough bolts fitting loosely into cored holes in the lugs: the irregularities of the broken edges, fitting together, compel the halves always to assume the proper relative positions.

3486.

Pulleys should be bored out to fit their shafts closely. In the United States they are usually secured in place by pointed or cupped set-screws, and in England by taper keys. Large pulleys —for example, all those over 36 in. diameter for a 12-in. belt—should have a key in addition to the set-screws; but the key, which is half in the shaft and half in the pulley, should only fit on its sides (should clear top and bottom), and should never be tapered (see KEYS). Taper keys are difficult to fit, and tend to burst the hub; besides, in many positions in which pulleys are put, it is impossible or very difficult to drive in a key. The proper function of a key is merely that of preventing the pulley or coupling from turning on the shaft; and any attempt to make a taper key take the place of a good fit not only tends to burst the hub, but to confine the contact between the hub and the shaft to a single point, and thereby increase its tendency to work loose. Large pulleys subjected to excessive strains should be a very close fit to the shaft; and it is good practice to fit them exactly and force them to place with a screw-press. The chief objection to this plan is that, as it is impracticable to make the shaft of an exactly uniform diameter, it is necessary to leave that portion upon which the pulley is to fit a trifle larger than the rest of the shaft. The pulley may then be easily moved nearly to its place, and only requires forcing for the length of its hub. This plan, however, is open to the disadvantage that, if for any reason it becomes necessary to move the pulley along the shaft, it will be a loose fit at any other point. To obviate this difficulty, pulleys are often made with split hubs held together by stout bolts through the necessary lugs. They are bored a close fit to the shaft, and opened by a cold chisel or other wedge, pushed up to place, the wedge removed, and the bolts tightened. Pulleys thus made will fit any part of the shaft, and, as actual practice has shown, will hold without either set-screws or keys, although both are sometimes added.

To keep at the minimum the weight of the moving mass, its inertia and momentum, and the friction on the journals, it is very desirable to keep the pulleys (especially if the speeds are high) as light as is consistent with strength; and they should be varied to suit the character of their work. Thus, pulleys should be made heavier for double than for single belts, and heavier for a given width of face if high than if straight, because straight-faced pulleys are used only for shifting belts, which of course are much narrower than the face of the pulley. Thus a 30 × 12 in. pulley, *high face*, would probably carry a 12-in. belt, while a *straight-face* pulley of the same dimensions would probably only carry a 6-in. belt, and could well be made proportionately-lighter. Pulleys, once sold like other shaft-

ing parts at so much a pound, are now generally furnished at so much a piece, varying with the diameter, width of face, etc.

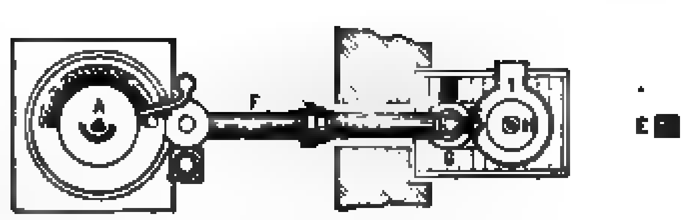
To increase the adhesion of the belt, pulleys are frequently covered or "lagged" with wood, leather, or India-rubber; but the fact seems to be that polished iron pulleys present a very close contact to the belt, and are only excelled by pulleys covered with leather, which appear to transmit about 20 per cent. more power.

Pulleys are made *high* (*crowning*) on their faces or *straight* (*flat*), according as they are to be used for stationary or shifting belts. Thus, in the ordinary case where we have a pulley on a main line driving two pulleys, one fast and one loose, on a countershaft, the driver is made flat because the belt is required to move easily sidewise on its surface, while the driven pulleys are made high in the middle of their faces (see *d* and *e*, Fig. 3487), as belts always climb to the highest point, and are thus kept in place in the centre. The shifting-forks, being placed near the driven pulleys, move the belt from one to the other, while it adjusts itself on the driver.

A very excellent method of arranging fast and loose pulleys is shown in Fig. 3487, where *a b* represents an ordinary countershaft, having its ends reduced to a smaller diameter for journals; and the loose pulley (*e*) is bored of the same diameter as the boxes, and is secured in place by the shoulder on the shaft and the hanger-box, while oil works from the box into the pulley and assists in its lubrication. Loose pulleys are provided with oil-holes and grooves to distribute the oil; and sometimes they have a reservoir cored out in the hub to hold the lubricant. Metaline (see Lubricants) has been used for lubricating the bearings of loose pulleys with successful results. C. S., Jr.

PUMPING ENGINES. It has become customary in this country to apply the term "pumping engine" to the large reciprocating pumping machines used for supplying cities and towns with water, draining lakes and marshes, and other similar extensive work. A pumping engine, strictly defined, includes a pump and its motor united in one machine. This definition, however, would embrace all the steam-pumps, however small their size or capacity. The term as commonly used can be regarded

3488.



therefore only as an arbitrary one, finding its justification in an apparent necessity for some distinguishing title for a class of apparatus specialized in its construction with reference to the magnitude and nature of the duty to be performed.

Early Pumping Engines.—From about 1758 up to the time of the introduction of the engine devised by James Watt, the Newcomen engine, as improved by Beighton, Smeaton, and others, was in almost

universal use for raising large quantities of water. In this machine the steam passed into the cylinder, equilibrating the pressure of the atmosphere and allowing the heavy pump-rod to fall. This rod, acting by its weight through a vibrating beam, thus raised the piston to the top of the cylinder. A jet of water was then turned into the cylinder, producing a vacuum by the condensation of the steam, and causing the air-pressure above the piston to force it down. Newcomen's first engine made from 6 to 8 strokes per minute; the later and improved engines made 10 or 12. The machine was simply an "atmospheric engine." It was converted into a steam-engine by the remarkable genius of Watt. To it he applied his first and greatest invention, the separate condenser. With the latter he combined the air-pump, to relieve it not only of the water but of the air, which also usually collects in considerable volume and vitiates the vacuum. He covered the top of the cylinder, causing the piston-rod to play through a stuffing-box, and surrounded the cylinder with a steam-jacket, through which steam from the boiler was conducted. These were the first endeavors to keep the steam-cylinder of an engine as hot as the steam which enters it—a problem which modern engineers are still seeking to solve.

Watt's first engine was erected at a coal-mine on the estate of the Duke of Hamilton at Kinneil, near Borrowstounness. It is represented in Fig. 3488. The steam passes from the boiler through the pipe *d* and the valve *e* to the cylinder-casing or steam-jacket *y*, and above the piston *b*, which it follows in its descent in the cylinder *a*, the valve *f* being at this time open to allow the exhaust to pass into the condenser *h*. The piston now being at the lower end of the cylinder and the pumps filled with water, the valves *c* and *f* close, while *e* opens, allowing the steam which remains above the piston to flow beneath it, until, the pressure becoming equal above and below by the weight of the pump, it is rapidly drawn to the top of the cylinder, while the steam is displaced above, passing to the under side of the piston. Now the valve *e* is closed and *c* and *f* are again opened, and the down stroke is repeated as before. The water and air entering the condenser are removed at each stroke by the air-pump *i*, which communicates with the condenser by the passage shown. The pump *g* supplies condensing water, and the pump *A* takes away a part of the water of condensation, which is thrown by the air-pump into the "hot-well" *k*, and with it supplies the boiler. The valves are moved by gear by the pins *m m* in the "plug-frame" or "tappet-rod" *n n*. *F* is an opening out of which, before starting the engine, the air is driven from the cylinder and condenser.

3490.

The invention of the expansion of steam and of the crank and fly-wheel resulted in material improvements in the engine as above described. It also was made double-acting. Up to this period the history of the pumping engine is substantially that of the steam-engine. Since the time of Watt improvements have tended to adapt the machine to particular applications, and thus the pumping engine becomes differentiated from the engines specially adapted to other uses.

The Cornish Pumping Engine is in all its general features the same as Watt's engine. It is
acting, and has a steam-jacket and
rovements are principally in the
l in its adaptation to high steam
inder, *B C* the piston and rod, *D*
ondenser is seen at *G*, and the air-
am-jacketed, and is surrounded by
a casing *O*, composed of brickwork or other non-conducting material. Steam is first admitted above the piston, driving it rapidly downward and raising the pump-rod. At an early point in the stroke the admission of steam is checked by the sudden closing of the induction-valve, and the stroke is completed under the action of expanding steam assisted by the inertia of the heavy parts already in motion. The necessary weight and inertia are afforded in many cases,

where the engine is applied to the pumping of deep mines, by the immensely long and heavy pump-rods. Where this weight is too great, it is counterbalanced; and where, as when used for the water-supply of cities, too small, weights are added. When the stroke is completed, the "equilibrium-valve" is opened, and the steam passes from above to the space below the piston, and, an equilibrium of pressure being thus produced, the pump-rods descend, forcing the water from the pumps and raising the steam-piston. The absence of the crank or other device which might determine absolutely the length of stroke compels a very careful adjustment of steam-admission to the amount of load. Should the stroke be allowed to exceed the proper length, and should danger thus arise of the piston striking the cylinder-heads, the movement is checked by buffer-beams. The regulation is effected by a "cataract," a kind of hydraulic governor, consisting of a plunger-pump with a reservoir attached. The plunger is raised by the engine, and then automatically detached. It falls with greater or less rapidity, its velocity being determined by the size of the eduction orifice, which is adjustable by hand. When the plunger reaches the bottom of the pump-barrel, it disengages a catch, a weight is allowed to act upon the steam-valve, opening it, and the engine is caused to make a stroke. When the outlet of the cataract is nearly closed, the engine stands still a considerable time while the plunger is descending, and the strokes succeed each other at long intervals. When the opening is greater, the cataract acts more rapidly, and the engine works faster. This has been regarded until recently as the most economical of pumping engines, and it is still generally used in Europe in freeing mines of water.

Fig. 3490 represents a lighter, cheaper, and almost equally effective machine, known as the Bull Cornish or direct-acting Cornish engine. It was first designed by the competitor of Watt by whose name it is known. As is seen by reference to the engraving, its cylinder *a* is directly above the pump-rods *c*, *d*, *g*, and is carried on cross-beams, *b b*. The air-pump *m l o p*, the tank *n*, and valve-gear *q r s*, are quite similar to those of the beam Cornish engine. The balance-beam is seen at *h i*.

The duty or useful effect of the Cornish pumping engine has been closely observed, and tabulated over a large number of years. It is found to have greatly improved in course of time. It is estimated by the number of pounds raised one foot high by a bushel of Welsh coal (94 lbs.). The following table shows the reported gradual increase in duty:

	Pounds 1 ft. high.
In 1769, the Newcomen engine	5,500,000
" 1772, " " improved by Smeaton	9,500,000
From 1778 to 1815, Watt's engine	20,000,000
In 1820, improved Cornish engine (average duty)	28,000,000
" 1826, " " "	30,000,000
" 1827, " " "	32,000,000
" 1828, " " "	37,000,000
" 1829, " " "	41,000,000
" 1830, " " "	43,350,000
" 1839, " " "	54,000,000
" 1850, " " "	60,000,000
Consolidated Mines, highest duty, 1827	67,000,000
Fowey Consols (Cornwall), highest duty, 1834	97,000,000
United Mines, highest duty, 1842	108,000,000

The Haarlem Lake Pumping Engines.—Beginning in 1847, three engines of special construction were erected for the purpose of draining Haarlem Lake in Holland. The area of this lake was 45,-230 acres, and the estimated contents to be pumped out was about 800,000,000 tons. The engines erected were respectively named the "Leeghwater," the "Cruquius," and the "Lynden," after three celebrated engineers who had at different periods proposed plans for the work. The Leeghwater was first erected, and on testing was found to give a duty of 75,000,000 lbs. (lifted 1 foot by 94 lbs. of Welsh coal), while exerting a net effective force of 350 horse-power, and consuming $2\frac{1}{4}$ lbs. of coal per horse-power per hour. The Leeghwater engine is described as follows: The two steam-cylinders are placed concentrically, one within the other, the diameters being 144.37 in. and 84.25 in. Both are united to the same bottom; but there is a clear space of $1\frac{1}{4}$ in. between the inner cylinder and the top. The large cylinder is jacketed. The areas of the pistons are as 1 to 2.85. The pistons are connected to a great cap or cross-head by one main and four small piston-rods. The engine works 11 pumps of 63 in. diameter each. Each pump has a cast-iron balance-beam, which radiates from the centre of the piston-rod; the inner and outer arms are of equal lengths from the centre gudgeon. The inner ends of the balance-beams are furnished with cast-iron rollers, working against a plate, fitted with guides for each roller, which is screwed up against the under side of the great cap; each beam is connected to the cap by two slotted bridles, to insure simultaneous upward motion during the up stroke of the engine. From the outer end of the balance-beam the pump-piston is suspended by wrought-iron rods, and an additional length of chain cable attached to the pump-piston. The steam- and pump-pistons both perform a stroke of 10 ft. in length. Each pump by calculation should deliver 6.02 tons of water per stroke, or 66.22 tons for the 11 pumps. Actual admeasurement of the quantity, however, showed the delivery to be 63 tons. The action of the engine is as follows: Steam being admitted into the small cylinder, the whole of the dead weight and pump-balance beams attached to the great cross-head are elevated with it, and the steam being cut off at such portion of the stroke as may be required, the remainder is effected by the momentum acquired by the dead weight and the pressure of the expanding steam upon the small piston (the pump-pistons at the same time make their down stroke); at the end of the up stroke a pause of one or two seconds is requisite, to enable the valves of the pump-pistons to fall out, so that upon the down stroke of the steam-piston they may take their load of water without shock. During this time it is necessary to sustain the

great cross-head and its load of dead weight at the point to which it was elevated by the up stroke, as otherwise it would fall back until the expanded steam under the small piston was compressed to a density equal to the pressure per square inch of the load lifted, or would cause a very violent shock upon the pump-valves by suddenly throwing them out against the sides of the pumps. To avoid these evils an ingenious hydraulic apparatus was devised, which operates as follows: When the engine makes its up stroke, plunger-poles (which form part of the dead weight) are lifted, and the water from stand-pipes and reservoirs provided for the purpose follows up the plunger-poles as fast as they are elevated. At the end of the stroke spherical valves instantly close, and the dead weight is suspended exactly at the point at which it had arrived—and, of course, if the valves are tight, could be maintained there for any given period: in consequence of all strain being thus removed, there is no pressure to close the valves of the pump-pistons beyond their own weight; therefore they fall out without the slightest shock. To make the down stroke, an equilibrium steam-valve and the hydraulic valve are opened simultaneously: the water from beneath the plungers escapes to the stand-pipes and reservoirs, and the steam from the small cylinder passes round to the upper side of the small and annular pistons, puts the pressure on the small piston in equilibrium, and presses upon the annular piston (beneath which a constant vacuum is maintained), in aid of the dead weight now resting upon the inner ends of the pump-balances: by the united effort, the pump-pistons are elevated and the water is discharged. Before the next stroke is made, the eduction-valve is opened and a vacuum formed over both pistons. The use of the two cylinders enables the engineman, by judiciously altering the expansion in the small cylinder, to command his work at all times without stopping the engine to take out or put in dead weight, as would be necessary for a single-acting one-cylinder engine, where dead weight only is used for lifting the water. Each engine has two air-pumps of 40 in. diameter and 5 ft. stroke. The steam is cut off in the small cylinder at from one-quarter to two-thirds the stroke, according to the load; and after expanding through the remainder of the stroke, it is still further expanded in the large cylinder.

Pumping by the three engines above named was continued from May, 1848, to July, 1852. For elevations and plans of the machines, see *Civil Engineer's and Architect's Journal*, vol. x., London, 1847. See also DRAINAGE. For application of other pumps to draining purposes, see PUMPS, CENTRIFUGAL.

Compound Pumping Engines, in which the steam exhausted from one cylinder is further expanded in the second, were first introduced by Hornblower in 1781, and were patented in combination with the Watt condenser by Woolf in 1804. Fig. 3491 represents an ordinary form of compound pump-

3491.

ing engine, having a double cylinder *A B*, and working the combined bucket and plunger or double-acting pump *J*. In its cylinders the steam is usually expanded from four to eight times.

The Worthington Duplex Pumping Engine.—This engine is referred to under PUMPS, STEAM. In its larger forms it is extensively used for the supply of water-works, and has achieved notable results in point of efficiency and economy of working. A perspective view of the engine is given in Fig. 3492, and its interior construction is shown in the sectional view, Fig. 3493. The machine consists of two pairs of steam-cylinders, *A B*, placed side by side, each pair driving a pump-plunger, *F*, attached to its piston-rod, and each having its valve-gear, *H L*, *M N*, actuated by the movement of the piston of the other. The full-pressure steam from the cylinder *A* expands in the cylinder *B*, and then passes to the condenser *C*. *D D* are the air-pumps, worked from the bell-crank lever *H*, by means of links *I K*. *Q R* are balanced steam-valves, *V V* the suction-valves, and *T T* the discharge-valves. Being many in number, they are quickly opened and closed, having but a small lift. There is no fly-wheel, and the valve-gear of each of these independent engines is controlled by the other in such a manner that when one pair of pistons is at the end of the stroke the other pair is in motion. At the end of the stroke the pistons are stationary an instant, before they recommence their motion, thus allowing the water-cylinder to be completely filled and the valves to be seated without shock.

3498.

THE WORTHINGTON DUPLEX PUMPING ENGINE.

Some particulars of the results of contract trials of these engines, furnished by the manufacturers, will be found in the accompanying table. All the trials were made in the manner which has been commonly adopted in duty tests, commencing the run with the fires in good condition, and charging all coal consumed thereafter until the conclusion of the test.

Results of Trials of Worthington Pumping Engine.

DETAILS.	Newark, N. J., January 28, 1879.	Salem, Mass., November, 1874.	Lowell, Mass., June 29, 30, 1876.	Fall River, Mass., October 4, 1876.
Duration of test, hours	8	207.52	22.77	13
Coal burned, lbs.	8,200	67,675	9,400	6,600
Number of strokes	21,776	664,641	15,637	31,876
Average length of stroke, in.	48.09	....	47.16	49.7
Average water-pressure, lbs. per sq. in.	75.68	....	62.118	94.02
Duty per 100 lbs. of coal, foot-pounds	77,157,840	79,850,100	60,000,488	70,977,177
Loss of action of pump, per cent.	1	....	2.25	....

The Worthington engine shows regular average yearly duties as high as 60,000,000, in which fuel necessarily expended on account of stoppages is included.

As regards economy of working, the following table is taken from the report of Mr. Charles E. Emery, C. E., one of the judges at the Centennial Exposition of 1876:

Table showing Comparative Cost of operating Pumping Engines at Philadelphia, Pa.

NAME OF PUMPING ENGINE.	TYPE OF ENGINE.	COST OF RAISING ONE MILLION GALLONS ONE FOOT HIGH.				
		1872.	1873.	1874.	1875.	1876.
		Cents.	Cents.	Cents.	Cents.	Cents.
Belmont	2 Worthington Duplex	7	7.08	7.68	7.84	7.97
Roxborough	1 full Cornish and 1 Worthington Duplex	9.9	9.92	9.19	10.80	9.51
Delaware	1 high- and 1 low-pressure rotative and 1 Worthington Duplex, 2 full Cornish	18.2	18.14	14.85	12.99	12.69
Schuylkill	1 double-cylinder rotative, 1 bell-crank rotative	11.2	17.86	16.97	17.05	18.40
Germantown	1 high-pressure rotative	36.2	...	.....	.....	....

The same report states that "in the Worthington engines the weight and friction of moving parts are reduced to a minimum, and the elastic force of the steam practically acts upon the water-column directly, whereby is secured simplicity of construction and smoothness of working, with a material reduction of frictional resistance; also freedom from the danger incident to handling the heavy weights in the original form of non-rotative engines. The expansion of steam in the Worthington pumping engine is determined principally by the size of the compound cylinders, and is sufficient, in connection with the freedom from jar and the low resistance of engines and pumps, to secure duties which are quite high, when it is considered that the maximum steam-pressure so far employed is only

3494.

THE HOLLY PUMPING ENGINE.

40 lbs." From 1860 to 1876 no less than 80 of these engines, with capacities varying from 600,000 to 15,000,000 gallons daily, were erected in different parts of the United States and Canada. Full particulars of these, together with a complete discussion of the Worthington system of pump construction, will be found in a work on the subject published by the manufacturers.

The Holly Pumping Engine is illustrated in Figs. 3494, 3495, and 3496. Fig. 3494 is a perspective view, Fig. 3496 a section, and Fig. 3495 represents the regulator. The engine shown is that erected by the Holly Manufacturing Company of Lockport at Buffalo, N. Y., for the supply of the water-works of that city. Results of duty trials made upon the machine by Park Benjamin's Scientific Expert Office, expressly for this work, will be found in another part of this article, under "Duty Trials of Pumping Engines." This engine has four steam-cylinders, inclined at an angle of 45°, and four pumps, one of which is in a direct line with each cylinder. The steam-cylinders and their pumps are arranged in pairs, on opposite sides of a heavy iron frame, the two cylinders of each pair being connected to a common crank-pin, and the crank for one pair of cylinders being set 135° in advance of that on the opposite side. The engines are of the reciprocating-piston form, with guides and connecting-rods. A connecting-rod attached to the back crank-pin actuates an air-pump beam, giving motion to two single-acting air-pumps and two boiler feed-pumps, one of which draws water from the hot-well, and the other from the steam jackets which surround the sides of all the steam-cylinders. The steam from the jackets passes through a feed-water heater, so that the temperature of the feed can be raised to any desired point by increasing the amount of steam supplied to the jackets. The connection of the pumps with the steam-cylinders, and of the steam piston-rods with the cross-heads, is by means of keys, so that any engine or pump can readily be thrown out of action. Each steam-piston is packed by cast-iron rings, set out by a spring, the set-screw of which projects beyond the face of the piston; and there are bonnets in the upper cylinder-heads, so that the piston-rings can be adjusted without removing the cylinder-covers. The pumps are of the piston variety, double-acting, the pump-barrel being secured in a chamber containing the valves by a rib which forms a partition between valves on the opposite ends. The pump-valves are flat disks of rubber, secured to iron disks having stems working in guides. These iron disks are of sufficient weight to bring the valves to their seats promptly, and no springs are used. The valves seat on metal gratings.

3495.

The steam- and exhaust-pipes of the several steam-cylinders are so arranged that steam from the boilers can be admitted directly into all the cylinders, and exhausted into the condenser, or live steam can be admitted to but one cylinder, and exhausted into the other three, thence passing to the condenser, thus forming a compound engine, at pleasure. To change from direct to compound, it is only necessary to manipulate three valves, one connecting the steam-pipe of three cylinders with the boilers, one connecting the exhaust-pipe of the fourth cylinder with the condenser, and the third one connecting the exhaust-pipe of one cylinder with the steam-pipe of the other three. The valve-gear of each steam-cylinder consists of a slide-valve moved by an eccentric in the usual manner, and admitting steam throughout the whole stroke. A double puppet-valve in the steam-chest regulates the point of cut-off, being actuated by a revolving spiral cam, which can be moved in an axial direction and thus vary the period of admission from zero to full stroke. The manner in which this cam is moved so as to regulate the speed and power exerted, constitutes the chief peculiarity of the Holly pumping engine. The adjustment is effected by means of a regulator connected with the main in such a manner that any change in water-pressure is immediately corrected by an adjustment of the cut-off, resulting in a practically uniform water-pressure under the most varying conditions of supply. Referring to Fig. 3494, it will be seen that there is a small water-cylinder containing a solid piston, connected directly with the main, and a weight is attached to the piston, so as to counterbalance the water-pressure. This is effected by suspending the weight from a strap which passes over a cam that rotates as the pressure varies, thus changing the lever-arm of the counterbalance, and keeping it in equilibrium with the water-pressure, however much the latter may vary. The cut-off cams of the steam-cylinders are moved axially, either to shorten or lengthen the cut-off, when the regulator throws a friction-clutch into gear, which it does whenever the water-pressure varies from a given amount. A weighted lever would maintain this friction-clutch in gear continually were it not for the action of the regulator. The shaft on which the counterbalance-cam rotates has an index-wheel, and index that can be set at any desired water-pressure. So long as the water-pressure varies from the figure at which the index is set, the friction-clutch is kept in gear by the weighted lever, and the cut-off is adjusted until the required pressure is reached. At this point the index engages with the weighted lever, and throws the friction-clutch out of gear. Whenever the water-pressure varies, the

friction-clutch is thrown into gear again, changing the cut-off, so as to maintain the water-pressure constant. It will be seen that the cut-off is regulated by positive gear driven by the engine, and the only work required of the regulator is to connect or disconnect this gear. Should the pressure rise very suddenly, however, a piston in a safety-cylinder raises a lever to which the cut-off gear is connected, and throws the cut-off to zero instantly if this is requisite. A regulator, it is scarcely necessary to say, is an essential feature of a direct pumping system in which the supply constantly varies.

3496.

The Leavitt Pumping Engine is the design of Mr. E. D. Leavitt, Jr., C. E., of Cambridgeport, Mass. That which formed the subject of the test made by Park Benjamin's Scientific Expert Office, elsewhere described in this article, supplies the water-works at Lawrence, Mass. A perspective view of the machine is given in a full-page plate, and a sectional view in Fig. 3497. This is a compound beam-engine, the steam-cylinders of which are inclined outwardly at the top to connect with opposite ends of the working-beam. The cylinders are jacketed on the sides and heads, steam of boiler-pressure being used in the jacket of the high-pressure cylinder, and steam of a reduced pressure in the other jacket. The drainage from these jackets is ordinarily returned directly to the boilers; but on the occasion of the trial, the connections with the boilers were broken, and the jacket-drainage was allowed to mingle with the other feed-water drawn from the hot-well. The steam- and exhaust-valves are gridiron slides, giving large openings with small movements. The valves are actuated by cams which are driven by gearing from the crank-shaft, and a centrifugal governor adjusts the cams operating the steam-valves of the high-pressure cylinder, so as to vary the point of cut-off and maintain a constant engine-speed. The pump is driven by a connecting-rod attached to one end of the working-beam. The pump consists of a plunger to which is attached a bucket, with valve opening upward. There are seven receiving valves and four delivery valves, in addition to the valve in the bucket, the water being discharged from the pump through two delivery pipes, above and below the bucket respectively. The pump-valves consist of loaded rubber disks, with central guiding stems. The original valves were of metal, double-beat, and the introduction of the present form has greatly increased the pumping efficiency.

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The Corliss Pumping Engine.—A pumping engine on the Corliss system was constructed at Pawtucket, R. I., in 1878. It has two steam-cylinders, the pump piston-rods being continuations of the steam piston-rods. The pump piston-rods are continued through the pump-cylinders, and their front ends are connected to cross-heads working in guides. Connecting-rods attached to these

THE LEAVITT PUMPING ENGINE.

cross-heads give motion to two vibrating levers, one of which actuates the air-pump and the other the boiler feed-pump. Two main connecting-rods, attached to these swinging levers, with a leverage twice that at the point of connection with the pump piston-rods, and connected at their opposite ends to cranks, give motion to a fly-wheel shaft, the bearings of which are secured to rectangular-shaped air-vessels. The effect of this novel form of connection is obvious. The pump connecting-rods have but little angular vibration, thus materially lessening the friction on the guides. The steam-cylinders are arranged on the compound principle, steam being admitted from the boilers to one cylinder, and exhausted into a receiver, from whence it is admitted to the second cylinder, and is finally exhausted into the condenser. Both cylinders are steam-jacketed, with steam of boiler-pressure, on the sides and heads, and the jackets are drained by a pump which delivers the water into the boiler feed-pipe. The receiver is also drained by a second pump, and all condensed steam is reëvaporated in a heater in the boiler-flue and returned to the receiver. The engines are fitted with the well-known Corliss valves and valve-motion, the latter having the peculiarities of that used in the large Corliss engine in Machinery Hall at the Centennial Exhibition. The cut-off valves are controlled by a governor, which, however, acts ordinarily only when the speed of the engines is unduly increased; and a hand-lever is commonly used for regulating the point of cut-off.

The pumps consist of plungers working through packed rings. The pump-valves are arranged around the pump-barrels, and are thin disks of phosphor-bronze, kept to their seats by light spiral springs of a peculiar form, which also act as guides.

The boilers are of the vertical fire-tube pattern. The principal dimensions of the engines and boilers are as follows:

Principal Dimensions of the Corliss (Pawtucket, R. I.) Pumping Engines.

Diameter of high-pressure cylinder	15 in.	Diameter of force-main	20 and 24 in.
" of low-pressure cylinder	30 "	Length of force-main, 12,300 ft., 24 in. in diameter, and 7,800 ft., 20 in. in diameter.	
" of pump-plungers	10.52 in.	Diameter of suction-pipe	15 in.
" of all piston-rods	2.5 in.	" of steam-pipe	6 "
Stroke of cylinder and pumps	30 in.	" of exhaust-pipe	7 "
Effective area of pump-plunger	82.012 sq. in.	" of receiver	16 "
Displacement of both pumps per revolution	5.6953 cub. ft.	Length of receiver	121 "
Diameter of air-pump, single-acting	20 in.	Diameter of condenser	10 "
Stroke of air-pump	7 "	Length of condenser	53 "
Number of valves in each pump	280,	Diameter of fly-wheel shaft	6 "
Area of opening, receiving, and delivery valves at each end of pump	122.64 sq. in.	Length of " "	18 ft.
		Length of engines over all	34 "
		Width of " "	19 "
Capacity of air-vessel	10.75 cub. ft.	Height of " "	19 "

Principal Dimensions of the Boilers.

Number of boilers	3	Total water-heating surface	1231.5 sq. ft.
Diameter of each boiler	4 ft.	" superheating surface	508.8 "
Height of " "	14 "	" cross-section of tubes	6.09 "
Number of tubes in each boiler	48	Ratio of water-heating surface to grate-surface	29.5
Outside diameter of tubes	3 in.		
Diameter of grate	5 ft.	Ratio of cross-section of tubes to grate-surface	0.103
Total grate-surface in boilers	58.905 sq. ft.		

Reports of duty trials of this engine will be found in the *American Machinist*, vol. i., No. 12, and vol. ii., No. 15, and in *Engineering*, xxviii., 189.

Duty Trials of Pumping Engines.—The "duty" of a pumping engine, to which reference is frequently made in this article, is the effective work of the engine, expressed in foot-pounds of work done for each 100 lbs. of coal consumed. The effective work of the engine is evidently the pressure in pounds per square inch under which the pumps deliver water, multiplied by the area in square inches of the pump-pistons producing this pressure, and by the distance in feet travelled by the piston. The duty therefore $= \dfrac{P \times A \times S \times R \times 100}{C}$; in which expression, $P =$ water-pressure, in pounds per square inch; $A =$ area of all pump-pistons, in square inches; $S =$ feet travelled by all pump-pistons per revolution or double stroke; $R =$ total revolutions or double strokes of engine; and $C =$ pounds of coal burned.

Whether the effective work of the engine is also useful work depends upon the condition of the pumps; and the actual capacity of the engine can only be determined by a test in which the water delivered by the pumps is measured. It will be evident, however, that the effective work of the engine is measured by the speed of the pumps and water-pressure due to their action, whatever be the amount of water delivered. In other words, the pump performs an office somewhat similar to that of the friction-brake, indicating what amount of work can be done by the engine if the pump is delivering water. Of course, a pump which does not deliver water is of no practical use; but as pumps are ordinarily constructed, any loss of action is attended by a reduction in the water-pressure, so that the above expression for the calculation of duty will give results that are substantially correct if proper care is observed in noting the required data. These data, aside from the dimensions of the pump (as will be seen by a reference to the formula for duty), are three in number: 1. The

number of revolutions, or double strokes; 2. The water-pressure; 3. The amount of coal burned. The number of revolutions can be readily ascertained by the indications of a counter; the water-pressure can be obtained from the readings of one or more accurately-adjusted gauges; and accurate scales are the only apparatus required for determining the weight of coal consumed.

In spite, however, of the ease with which these elements can be determined, they have not been measured accurately in any tests made in this country that have been brought to the attention of the writer, with a single exception—guesses and assumptions being resorted to, in lieu of accurate observations. The nature of these assumptions may be briefly referred to. In the determination of the water-pressure, it has often been the custom to make an arbitrary allowance for the friction in certain portions of the pipes, beyond what is indicated by the gauges. But the greatest error has ordinarily been committed in what was assumed to be the amount of coal burned—it being the amount put into the furnace between the time of stopping and that of starting the trial, assuming that there was precisely the same weight of fuel in the fire, and in the same condition, at the commencement and conclusion of the run. The error in this mode of measurement has frequently been diminished by continuing the trial for a considerable period of time, so that any extra allowances become a smaller percentage of the actual consumption. These extended trials, however, requiring a large number of observers, usually involve such an expense as to be prohibitory, except in special instances.

From what has been said, the reader will perceive that a test of the duty of a pumping engine does not necessarily involve any assumptions, and does not require a large corps of observers, or very great expense; the elements necessary for the calculation being few in number, and readily obtained. In order to give prominence to this point, and at the same time obtain information in regard to the performance of pumping engines designed by prominent engineers in this country, Park Benjamin's Scientific Expert Office has made a series of tests of the Holly pumping engine at Buffalo, N. Y., and of the Leavitt pumping engine at Lawrence, Mass. In each of these experiments, the number of revolutions made by the engines was recorded by a counter. The water-pressure was measured in each instance by a spring-gauge connected to the main just above the level of the delivery valves of the pump, with other measurements, which will be described, of the pressure in the suction-pipe.

In the case of the Holly pumping engine, the water was delivered to the pumps under pressure, and a mercury-gauge connected to the suction-pipe just below the level of the receiving valves of the pump indicated the amount of pressure. The difference of level between the gauges on main and suction pipes was measured, whence the value of the water-pressure, in pounds per square inch, was:

$$\left(\begin{array}{c}\text{Average reading}\\ \text{of gauge on main}\end{array}\right) + \left(\begin{array}{c}\text{difference of level of gauges}\\ \text{in feet} \times 0.433\end{array}\right) - \left(\begin{array}{c}\text{average reading of}\\ \text{gauge on suction}\end{array}\right).$$

The pump of the Leavitt pumping engine was placed in the well, and a float indicated the distance between the level of water in the well and the pressure-gauge on the main, so that the water-pressure, in pounds per square inch, was:

$$(\text{Average reading of gauge on main}) + (\text{distance from level of water to gauge in feet} \times 0.433).$$

All the gauges used for indicating the pressure in the main were tested, both before and after the trial, by comparison with a differential mercury-gauge, the same test-gauge being used in all the experiments.

To determine the amount of coal consumed during the experiment, before commencing a run fires were hauled from the boiler furnaces, the ash-pits were cleaned, and the fires were immediately rekindled with coal and wood, which were charged to the experiment, each pound of wood being reckoned as equivalent to four-tenths of a pound of coal. At the time of starting the fires, the steam-pressure and water-level in the boilers were noted. As soon as the fires were in sufficiently good condition, the engines were started, and the trial commenced, all coal put into the furnaces being charged; and when, after the last firing, the steam-pressure had fallen to the point at which it stood when fires were started, the water-level being also the same, the trial was ended. The fires were immediately hauled and weighed, and as soon as practicable all unconsumed coal was picked out and weighed back, the remainder being charged as ashes. It seems difficult to conceive of a more accurate mode of measuring the coal consumed, so that a trial can be made with absolute accuracy in a short period of time, and all the observations can be under the control of a single expert.

In the experiments made by Park Benjamin's Scientific Expert Office, indicator diagrams were taken from steam- and pump-cylinders, in order to calculate the efficiency of the pumps. The scales of all springs used in the trials were determined by experiment, testing the springs used on the steam-cylinders under steam-pressure, and those used on pump-cylinders under water-pressure. This is a matter of considerable importance, where accurate results are desired, since the scale of a spring changes considerably when the spring is heated. The feed-water was measured in barrels placed upon platform scales. In the Holly engine test the feed-water was delivered to the barrels by the engine feed-pump, and was forced into the boilers by a steam-pump supplied with steam from an auxiliary boiler; and in the case of the Leavitt engine, the feed-water ran into the barrels from the hot-well.

I. *Test of the Holly Pumping Engine at Buffalo, N. Y., June* 26 *and* 27, 1879, *made by Park Benjamin's Scientific Expert Office. Trials conducted by Richard H. Buel, C. E.*

The construction of this engine is described on page 593. Its principal dimensions are as follows:

Number of steam-cylinders........	4	Diameter of shaft................	10 in.
Diameter of " "	25 in.	" of fly-wheel.............	12.33 ft.
Length of stroke of cylinders......	33 "	Width of rim of fly-wheel.........	10.25 in.
Diameter of piston-rod............	3.11 in.	Depth " "	8.5 "
Length of connecting-rod..........	8.25 ft.	Weight of fly-wheel..............	16,000 lbs.

Number of air-pumps	2
Diameter of "	24 in.
Stroke of "	30 "
Diameter of condenser	4.33 ft.
Length of "	29 in.
Diameter of main steam-pipe	8 "
" of steam-pipe for each engine	5 "
Diameter of main exhaust-pipe	10 "
" of exhaust-pipe for each engine	5 "
Extreme length of engine	43 ft.
" height "	26.75 ft.
" width "	17 ft.
Number of pump-cylinders	4
Diameter of pump-cylinders	15.5 in.
Length of stroke of pump-cylinders	33 in.
Diameter of piston-rod of pump-cylinders	2.86 in.

Displacement of all pumps per revolution	212 U S. gals.
Number of suction- and discharge-valves at each end	6
Area of opening of suction- and discharge valves at each end	147.96 sq. in.
Diameter of main suction- and discharge-pipes	24 in.
Diameter of suction- and discharge-pipes at each pump	14 "
Number of discharge air-vessels	4
Internal diameter of discharge air-vessels	22 in.
Internal height of discharge air-vessels (globe-shaped ends)	51 "
Number of suction air-vessels	4
Internal diameter of suction air-vessels	24 in.
Internal height of suction air-vessels (flat tops)	36 "

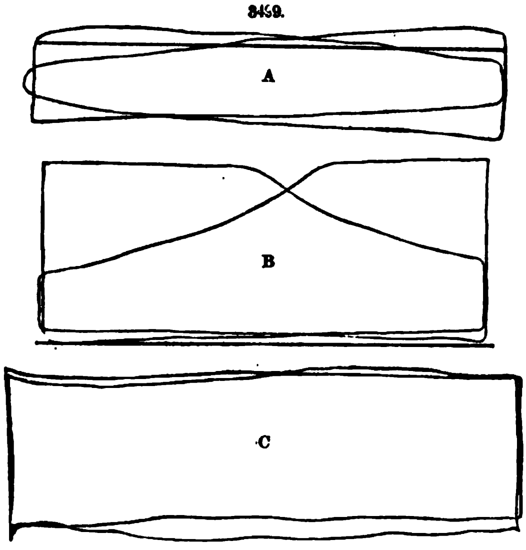
Two boilers were used to supply steam to the engines during the duty trial. They are internally fired, flue and return-tubular. The only protection against loss from radiation is a casing of light iron, a few inches away from the shells; and during the trials some hair felting, 1 in. in thickness, was laid loosely over some of the most exposed portions of the casing. The boilers are provided with steam-domes, from which the steam is supplied to the engines. The following are the principal dimensions:

Diameter of shell	6 ft.
Length of boilers	13.88 ft.
Number of flues in each boiler	3
Internal diameter of flues, one 16.75 in., two 11.5 in. each.	
Length of flues	4.65 ft.
Number of return-tubes in each boiler	86
Outside diameter of tubes	3 in.
Length of tubes	11.95 ft.
Total grate-surface	42.68 sq. ft.
Cross-section of flues	5.8 "

Cross-section of tubes	7.3 sq. ft.
Heating surface—tubes	1,608.3 "
" " furnaces	141 "
" " flues and connections	217.7 "
Total heating surface	1,967 "
Ratio of heating to grate surface	46.1
Ratio of cross-section of flues to grate surface	0.136
Ratio of cross-section of tubes to grate surface	0.17
Height of chimney above grate	76 ft.

Numerous indicator diagrams were taken from steam- and water-cylinders during the trial, and the results obtained from them will be found below. Three diagrams are illustrated in Fig. 3499—*A* from one of the low-pressure cylinders, *B* from the high-pressure cylinder, and *C* from one of the pumps. The scales of the springs were as follows: Low-pressure diagrams, 1 in. = 15 lbs.; high-pressure diagrams, 1 in. = 36 lbs.; pump diagrams, 1 in. = 30 lbs. During the time in which the diagrams were taken, the average revolutions of the engines per minute were 22.96; the average water-pressure was 46.5 lbs. per sq. in. The average pressures, deduced from the diagrams, were as follows: Low-pressure cylinders, 11.3 lbs. per sq. in.; high-pressure cylinder, 50.4 lbs. per sq. in.; pumps, 47.7 lbs. per sq. in. This gives, as the mean pressure on each steam-piston, $\frac{11.3 \times 3 + 50.4}{4} =$ 21.08; and the equivalent effective pressure on pump-pistons, reduced to area of steam-pistons, is $46.5 \times 0.384 = 17.86$; so that the efficiency of the pumps, as measured by the pressure in the main, was $\frac{17.86}{21.08} = 0.847$.

3499.



Results of duty trial, June 26, 27, 1879.

Duration of trial, 18.07 hours.

Average reading of gauge on main, 54 lbs. per sq. in.; on suction, 10.5 lbs. per sq. in.; pressure equivalent to difference of level between gauges, 2 lbs. per sq. in.

Pressure under which the pumps delivered water, $54 + 2 - 10.5 = 45.5$ lbs. per sq. in.
Total revolutions of engines, 23,092.
Effective area of pump-piston, 185.475 sq. in.; distance traveled by all pump-pistons per revolution, 22 ft.
Pounds of wood put into the furnaces, 532; of coal, 5,292; of unconsumed coal withdrawn from furnaces on completion of trial, 530; of coal consumed, $0.4 \times 532 + 5,292 - 530 = 4,975$.

$$\text{Duty, } \frac{45.5 \times 185.475 \times 23,092 \times 22 \times 100}{4,975} = 86,176,315 \text{ ft. lbs.}$$

The preceding are all the observations necessary for calculating the duty, but others that were taken will doubtless be found interesting:

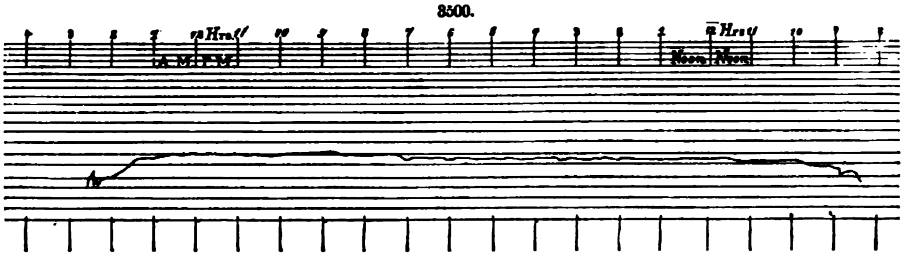
Average pressure, by gauge, in steam-pipe, 67.9 lbs. per sq. in.; in condenser, 24.9 in. of mercury.
Average revolutions of engines per minute, 21.3.
Average temperature of feed-water, 110°.
Delivery of pumps in 24 hours, calculated from piston displacement, 6,502,000 U. S. gallons.
Total quantities—Pounds of coal, 4,975; of ashes, 313; of combustible, 4,582; of feed-water, 54,900. Percentage of ashes, 6.39.
Hourly quantities—Pounds of coal, 275.3; of combustible, 258; of feed-water, 3,038.2; of coal per sq. ft. of grate, 6.45; of combustible per do., 6.07; of coal per sq. ft. of heating surface, 0.14; of combustible per do., 0.131.
Pounds of water evaporated—from temperature of feed, per lb. of coal, 11.04; per lb. of combustible, 11.78; per sq. ft. of heating surface per hour, 1.54; from and at 212°, per lb. of coal, 13.63; per lb. of combustible, 14.54; per sq. ft. of heating surface per hour, 1.9.

Horse-power—effective, deduced from water-pressure, 119.85; indicated, $\left(\frac{119.85}{0.847}\right) = 141.55$.

Consumption of coal and water per horse-power per hour—Pounds of coal per indicated horse-power, 1.94; per effective do., 2.31; of combustible per indicated horse-power, 1.82; per effective do., 2.17; of feed-water per indicated horse-power, 21.46; per effective do., 25.51.

After completing the duty trial, a few experiments were made to show the ease with which pumps could be disconnected or connected, and the engine be changed from direct to compound or the reverse. It was found that the latter changes could readily be made without stopping the engine; and when the engine was running with only two pumps connected, the other two were attached, and the original water-pressure was obtained, in 1 min. 8 sec. from the time of starting. Numerous experiments were also made to test the efficiency of the regulator, and it was found to act promptly in

3500.



every instance. Fig. 3500 is a diagram taken with an Edson recording gauge of the water-pressure during the test, which will serve to illustrate the action of the regulator.

II. *Test of the Leavitt Pumping Engine at Lawrence, Mass., July* 24, 1879, *made by Park Benjamin's Scientific Expert Office. Trials conducted by Richard H. Buel, C. E.*

A description of this engine will be found on page 594. The engines at Lawrence are designated as "A" and "B," and the trial in question was made with the "A" engine.

Principal Dimensions of the Engines.

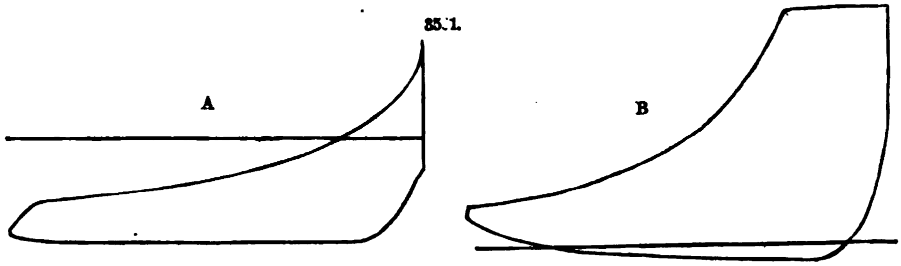
Diameter of high-pressure cylinder..	18 in.	Clearance, high-pressure cylinder, bottom....................	2.31 per cent.
" of low-pressure " ..	38 in.	Clearance, low-pressure cylinder, top..........................	1.54 "
" of pump-barrel...........	26.125 in.	Clearance, low-pressure cylinder, bottom......................	1.82 "
Stroke of steam- and water-pistons...	8 ft.	Connecting-pipe between cylinders, 9.92 per cent. of high-pressure cylinder capacity.	
Diameter of high-pressure piston-rod.	3.5 in.	Area of opening, receiving valves.	500.29 sq. in.
" of low-pressure "	4 in.	" " delivery "	285.88 sq. in.
" of plunger "	4.5 in.	Length of force-main...........	4,900 ft.
" of "	18.5 in.	Diameter of "	30 in.
" of air-chamber...........	54 in.	" of branch to pump....	24 in.
" of air-pump.........	15 in.		
Stroke of "	28 in.		
Diameter of fly-wheel..............	30 ft.		
Weight of fly-wheel................	35,900 lbs.		
Clearance, high-pressure cylinder, top	2.56 per ct.		

There are two internally fired tubular boilers, with combustion-chambers, and having return-flues beneath their shells. One boiler was used in the test, and the principal dimensions are as follows:

Length of boiler	25.46 ft.	Heating surface in furnaces	115 sq. ft.
Diameter of circular shell	5.25 ft.	" " in combustion-chamber	158 "
Number of tubes	80	" " in tubes	573.5 "
Outside diameter of tubes	3 in.	Total heating surface	1,020 "
Grate-surface	28.75 sq. ft.	Ratio of heating to grate surface	35.5
Heating surface in external shell	173.5 "	" of cross-section of tubes to do.	0.117

Two indicator diagrams, *A* from the low-pressure cylinder, and *B* from the high-pressure cylinder,

3501.



are shown in Fig. 3501. Numerous other diagrams, similar to those illustrated, were taken during the test, and the results obtained from them are appended:

Scale of spring, high-pressure diagrams .... 1 in. = 39.1 lbs.
Do., low-pressure diagrams .. 1 in. = 11.65 lbs.
Indicated pressure, high-pressure diagrams .... 51.57 lbs. per sq. in.
Do., low-pressure diagrams ... 8.46 " "
Water-pressure during time in which diagrams were taken . 76.7 " "
Pressure on high-pressure piston, reduced to equivalent pressure on pump-piston ... 48.18 lbs. per sq. in.
Pressure on low-pressure piston, reduced to equivalent pressure on pump-piston ... 35.51 " "
Sum of the two .... 83.69 " "
Efficiency of pumps .... $\frac{76.7}{83.69} = 0.91643$

The following are the results obtained on the duty trial:

Duration of trial, 15.1 hours.
Pounds of wood used to start fires, 400; of coal put into furnaces, 3,500; of coal withdrawn from furnaces at end of trial, 27; of coal consumed, $400 \times 0.4 + 3{,}500 - 27 = 3{,}633$.
Pressure in main, by gauge, 64 lbs. per sq. in.
Water-level in well below gauge, 29.05 ft.
Water-pressure, $29.05 \times 0.433 + 64 = 76.6$ lbs. per sq. in.
Area of pump-bucket, 536.0465 sq. in.
Revolutions of engine, 12,337.

$$\text{Duty of engine, } \left(\frac{536.0465 \times 8 \times 12{,}337 \times 76.6 \times 100}{3{,}633}\right) = 111{,}548{,}925 \text{ ft. lbs.}$$

Some other observations, and results deduced from them, are added:

Average revolutions per minute, 13.62.
Steam-pressure, by gauge, 89.5 lbs. per sq. in.
Vacuum, 27.4 in. of mercury.
Barometer, 29.81 in.
Temperature of engine-room, 79°; of feed-water, 119°; of flue, 358°.
Total quantities—Pounds of coal, 3,633; of ashes, 223; of combustible, 3,410; of feed-water, 36,800. U. S. gallons of water pumped per 24 hours, calculated from pump capacity, 4,401,272. Per cent. of ashes, 6.14.
Hourly quantities—Pounds of coal, 241; of combustible, 226; of coal per sq. ft. of grate, 8.38; of combustible per do., 7.86; of coal per sq. ft. of heating surface, 0.236; of combustible per do., 0.222; of feed-water, 2,437.
Evaporation—Pounds of water per lb. of coal, at observed temperature and pressure, 10.13; per lb. of combustible, do., 10.79; per sq. ft. of heating surface per hour, do., 2.39; per lb. of coal from and at 212°, 11.49; per lb. of combustible, do., 12.24; per sq. ft. of heating surface per hour, do., 2.71.

Horse-power—Net (calculated from water-pressure), 135.55; indicated, $\left(\frac{135.55}{0.91643}\right) = 147.91$.

Pounds of coal and water per horse-power per hour—Coal, per net horse-power, 1.78; per indicated do., 1.63; feed-water per net horse-power, 17.98; per indicated do., 16.48.

In addition to the experiments already detailed, the amount of water drained from the cylinder-jackets was measured for a period of two hours in the case of each jacket, giving, as the hourly discharge, in pounds—from high-pressure jacket, 112; from low-pressure do., 168; from both, 280.

R. H. B.

PUMPS. Machines for raising liquids in pipes, either by direct action or by atmospheric pressure, and also for exhausting air from vessels. (See AIR-PUMP.) In its simplest form a pump consists of a cylinder containing a tightly-fitting piston. At the bottom of the cylinder is a pipe communicating with the liquid to be raised, and a valve which opens from beneath. A similar valve is placed in the piston. Supposing the piston to be at the top of the cylinder, which together with the pipe is filled with air, as the piston is forced down it compresses the air in the cylinder, so that the valve in the piston opens and allows the air to escape. When the piston is raised, a vacuum is produced in the cylinder beneath it, and the pressure of the air on the liquid outside of the pipe forces it up into the latter, opens the valve in the bottom of the cylinder, and causes some of the air in the pipe to enter the cylinder. After a few strokes, the water will be forced into the cylinder, and then, as the piston descends, the water will rise through the valve in the piston, and be carried out on the upward stroke. If, however, the pump cylinder is placed at a greater distance above the surface of the water than the height of a column of water equal in pressure to the atmosphere (about 33.8 feet), no water will be forced into the cylinder. In ordinary practice, the distance which a pump will lift water seldom exceeds 28 feet; but the water can be forced to any desired height by placing a valve opening upward in the force-pipe. The force-pipe of a pump usually contains an air-chamber, for the purpose of preventing shocks, and for producing a steady discharge; and air-chambers are also frequently attached to the suction-pipes for a similar purpose.

Pumps may be classified in a variety of ways. Thus they may be divided into suction- and force-pumps, as above indicated. With regard to form, they may be reciprocating or rotary; and with respect to mode of driving them, they may be constructed so as to be operated by manual power, or by steam or other motor. In the latter case, the motor may be either independent or form a complete machine in combination with the pump. There are also various kinds of pumps which form separate types, such as vacuum-pumps and chain-pumps. Again, pumps may be classified with reference to special uses to which they are specifically adapted by their form, as in the case of pumps used for draining deep mines, etc. It will be apparent from the foregoing that any classification of pumping apparatus must be more or less arbitrary, and therefore it has seemed most logical to place under the heading PUMPS such apparatus as is independent of the motor, or rather that to which any suitable motive power may be applied; under PUMPS, STEAM, those machines which form a specific class of manufacture, and which consist of both pump and steam-motor combined; and lastly, under PUMPING ENGINES, a group of large machines adapted to particular purposes, which strictly belong to the steam-pump class, but which are separately recognized in view of their size and use.

The history of pumps, and descriptions of a large variety of forms, will be found in Ewbank's "Hydraulics," New York, 1863. For the theory of pump construction see Weisbach's "Mechanics of Engineering," Part I., vol. ii., "Hydraulics and Hydraulic Motors," New York, 1877. See also the lists of works for reference quoted under the various subjects (CANALS, DOCKS, BARRAGE, etc.) relating to hydraulic engineering. The efficiency of various forms of pumps is considered in treating of the different types.

RECIPROCATING PUMPS.

The essential parts of these pumps are the barrel, the piston which reciprocates therein, and the valves which allow of the escape or entrance of the liquid, or prevent its return. The diameter of the cylinder is generally greater than that of the suction- or the discharge-pipes, and is calculated in inches by the following formula: $D = \sqrt{\frac{G}{.034\,L\,N}}$, in which G represents the quantity in gallons to be delivered per minute, L the length of the stroke in feet, and N the number of single strokes a minute. To find the quantity in gallons that a given pump is capable of delivering per minute, $G = .034\,D^2\,L\,N$; and to find the quantity in gallons delivered at each stroke, $G = D^2\,S \times .00283$.

The Suction-Pump is the simplest form of pumping apparatus, and its principle of operation as such has already been described. It is inoperative when the liquid is to be lifted to heights greater than 33.8 ft., when situated at the ocean level, and this distance is decreased in proportion to the weight of the atmospheric column when the pump is placed on elevations. The construction of the pump is shown in Fig. 3502. A is a cylinder or barrel, in which a piston P is moved up and down by means of a piston-rod R attached to the extremity of the lever H. In the piston is a valve v lifting upward; and at the bottom of the barrel is another valve, V, also lifting upward. B is a pipe, passing from the bottom of the barrel into the well from which the water is to be raised. On the downward stroke of the piston, the valve V closes, and the valve v opens and allows the water to pass to the upper side of the piston. In an upward stroke the valve v closes and the valve V opens, and by the pressure of the atmosphere the water follows the piston in its ascent, whereas the water above the piston is pushed before it, and thus the fluid is discharged in a stream at the mouth C of the pump; and so on to any number of strokes.

The Lift-Pump is simply a modification of the suction-pump, as shown in Fig. 3503. The only change is the addition of the valve X in the delivery-pipe C. This valve shuts on the down stroke of the piston and retains the liquid column, so that the liquid may be raised to a height corresponding to the amount of power applied. It will readily be seen that by removing the lower valve and immersing the pump until the valve in the piston is below the surface of the fluid to be elevated, the machine becomes simply a water-lift. A common form of lift-pump has a piston-rod which enters the barrel from beneath and pushes the piston up, instead of lifting it through a box at the top of the cylinder.

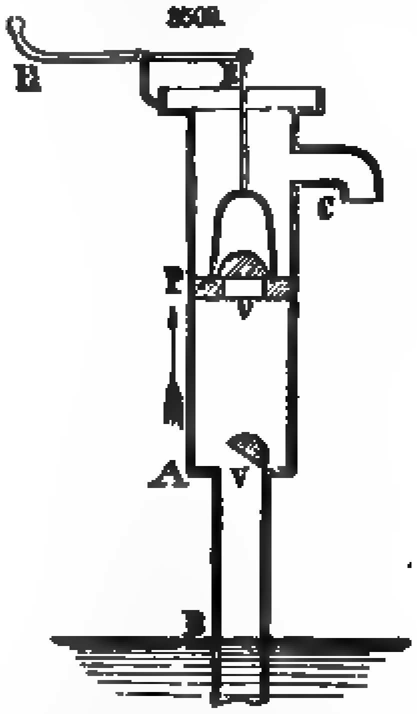
The Force-Pump.—From Fig. 3504 the difference between the lift- and the force-pump will be readily understood. While the former raises the liquid bodily above its piston through which the liquid passes, the latter forces it out of the barrel from beneath the piston, which is made solid. When the piston P rises the valve V opens, and the valve v in the delivery-pipe is closed by the air-pressure. The liquid then enters the barrel beneath the piston. On the descending stroke the valve

V closes, preventing the return of the water, and the valve *v* opens, so that the liquid, being pressed before the piston, is driven up the pipe *D* to the higher level required.

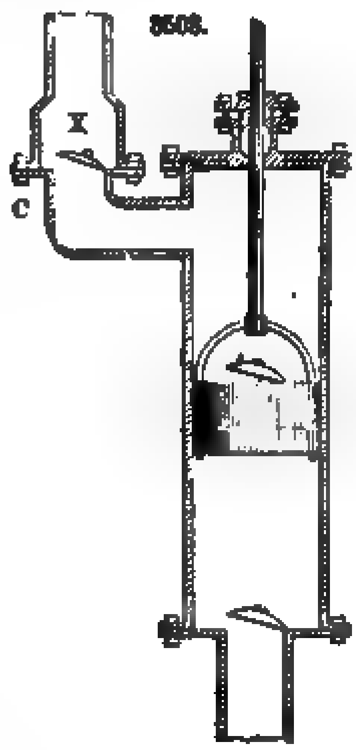
Modifications of these three kinds of pumps exist in great variety. As illustrations, several of the simplest and best known forms are here introduced.

The Double-Acting Force-Pump is shown in Fig. 3505. This has the advantage of producing a more uninterrupted stream than the form shown in Fig. 3504. When the solid piston-head *P*

3502.



3503.



3504.

descends, the valves *a* and *e* are shut, while *d* and *c* are opened, water entering behind the piston through *d*, and being forced in front of it through *c* and up the pipe *C D*. When the piston is raised, the position of the valves is reversed, the water entering through *a* and being forced out through *e*. This is the position shown in the figure.

The Plunger-Pump, Fig. 3506, is used when water is to be raised to a great height or against great resistance, as in the hydraulic press. (See PRESS, HYDRAULIC.) The plunger passes through a tightly-packed box as shown. On entering the cylinder it displaces and expels a quantity of water equal to its own volume through the upper valve, and on being withdrawn allows of the entrance of the same quantity through the lower valve.

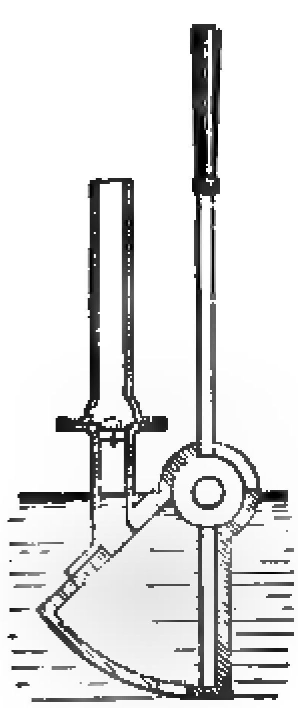
The Force-Pump with Air-Chamber is represented in Fig. 3507. The object of the air-chamber is to produce a constant and equable flow, and to avoid the sudden shock of reaction. It consists of a dome-shaped vessel placed in the discharge-pipe a short distance beyond the upper valve. The entrance of the water causes a compression of the air, which thus exerts a continuous pressure. In the common force-pump the water is discharged only at each downward stroke of the piston, whereas,

3505. 3506. 3507.

in the present case, the pressure of the air in the chamber sustains the discharge during the intervals taken up by the upward strokes of the piston. A pump of this class combined with a portable reservoir is represented in Fig. 3508.

Fig. 3509 is an arrangement of lifting- and force-pump so placed beneath the surface of the ground and water that it cannot freeze in cold weather. The air-chamber is located some distance above the water. The pump-barrel is submerged and connected to the air-chamber by a pipe. The delivery-pipe may be brought directly to the surface, or water may be led to some distance from the pump by a branch pipe as shown. The pump rod passes down through a stuffing-box in the air-chamber.

3512.



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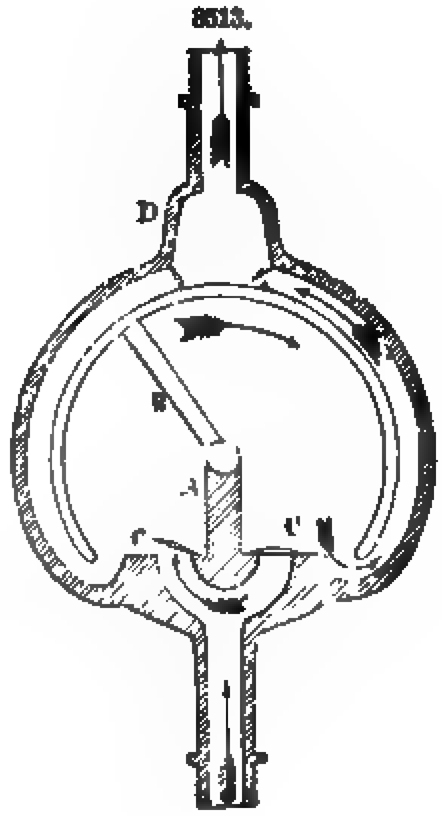


3514.

Fig. 3510 represents the siphon-working barrel-pump for deep wells, made by the Gould Manufacturing Company. Within the outer barrel is a second cylinder, in which the piston works. There is an air-space of about one inch between the two barrels. The induction-pipe enters the outer barrel at some distance above the lower valve, so that the valves, being always submerged, do not get dry and hard, and the pump is always primed.

The so-called fire-engine pump, shown in Fig. 3511, is a combination of two force-pumps, the water being forced from each into the common air-chamber A, and so on through the discharge-pipe E, to which may be attached the hose. (See ENGINES, FIRE.)

Oscillating-Piston Pumps.—Two examples are given in Figs. 3512 and 3513 of pumps the barrel of which is made segmental in form, and in which the piston is turned on a centre by a lever. In Fig. 3512 the case has an opening below through which the liquid enters, and another above provided with a valve out of which it is forced.

In Fig. 3513 there is a short horizontal cylinder; a portion of the lower part is separated from the rest by a plate where the suction-pipe terminates in two openings that are covered by clacks $C\,C$. The partition A extends through the entire length of the cylinder, and is made air- and water-tight to both ends, and also to the plate upon which its lower edge rests. The upper edge extends to the under side of the axle to which the piston B is united. One end of the axle is passed through the cylinder and the opening made tight by a stuffing-box; it is moved by a crank or lever. Near the clacks $C\,C$ two other openings are made through the plate, to which the forcing-pipes are secured. These tubes are bent round the outside of the cylinder and meet in the chamber D, where their orifices are covered by clacks. Thus, when the piston is turned in either direction, it drives the water before it through one or other of these tubes; at the same time the void left behind it is kept filled by the pressure of the atmosphere on the surface of the liquid in which the lower orifice of the suction-pipe is placed.

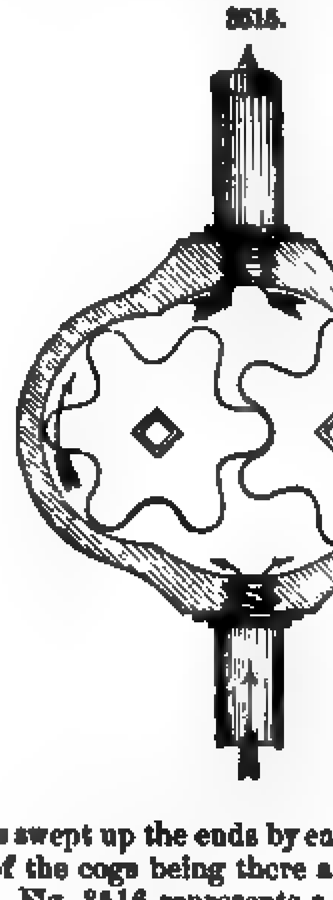
The Chain-Pump may be regarded as one form of lifting-pump, though strictly it is a water-elevator, having few of the characteristics of a pump, and all the essential features of the elevators used for lifting grain. The pistons corresponding to the grain-buckets are placed on an endless chain $A\,B$, Fig. 3514, which passes through the tubes E and C and over the sprocket-wheels Q and J. The liquid is lifted by the pistons and is discharged at the top of the tube B.

ROTARY PUMPS.

This class of pumps differs from the centrifugal pump, which is described elsewhere in this article, in that it includes a revolving piston, while in the centrifugal pump there is a set of revolving blades which act upon the liquid in the same way as a fan acts upon the air. The rotary pump substantially corresponds to the pressure-blower, and in many cases is simply the rotary engine reversed; while the centrifugal pump is analogous to the fan-blower. A very large number of forms of rotary pump are illustrated in Reuleaux's "Kinematics of Machinery," and in Ewbank's "Hydraulics." Several of the best known types are given herewith.

Fig. 3515 represents one of the oldest and most efficient forms. Cog-wheels, the teeth of which are fitted to work accurately into each other, are inclosed in an elliptical case. The sides of these wheels turn close to those of the case, so that water cannot enter between them. The axle of one of the wheels is continued through one side of the case (which is removed in the figure to show the interior), and the opening made tight by a stuffing-box or collar of leather. A crank is applied to the end to turn it, and as one wheel revolves it necessarily turns the other, the direction of their motions being indicated by the arrows. The water that enters the lower part of the case is swept up the ends by each cog in rotation; and as it cannot return between the wheels in consequence of the cogs being there always in contact, it must necessarily rise in the ascending or forcing pipe.

3515.



3516.

Fig. 3516 represents a pump similarly constructed to the foregoing, but having cams shaped so as to reduce the wear.

In Eve's pump, shown in Fig. 3517, a solid or hollow drum A revolves in a cylindrical case. On the drum are three projecting pieces, which fit close to the inner periphery of the case. The surface of the drum revolves in contact with that of a smaller cylinder B, from which a portion is cut off to form a groove or recess sufficiently deep to receive within it each piston as it moves past. The diame-

ter of the small cylinder is just one-third that of the drum. The axles of both are continued through one or both sides of the case, and the openings made tight with stuffing-boxes. On one end of each axle is fixed a toothed wheel of the same diameter as its respective cylinder; and these are so geared into one another, that when the crank attached to the drum-axle is turned (in the direction of the arrow) the groove in the small cylinder receives successively each piston, thus affording room for its

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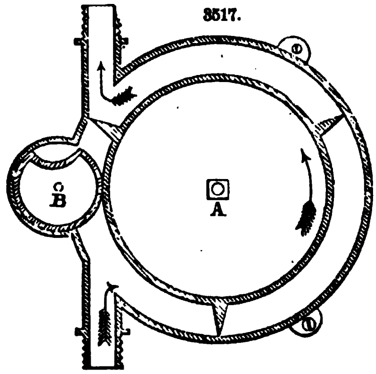

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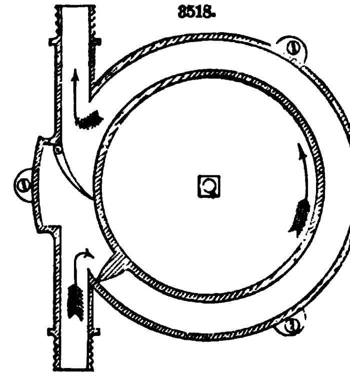

passage, and at the same time, by the contact of the edge of the piston with its curved part, preventing water from passing. As the machine is worked, the water that enters the lower part of the pump through the suction-pipe is forced round and compelled to rise in the discharging one, as indicated by the arrows. Other pumps of the same class have such a portion of the small cylinder cut off, that the concave surface of the remainder forms a continuation of the case in front of the recess while the pistons are passing; and then, by a similar movement to that in the figure described, the convex part is brought in contact with the periphery of the drum until the return of the piston.

In the pump shown in Fig. 3518, the abutment consists of a curved flap turning on a hinge, so arranged as to be received into a recess formed on the rim or periphery of the case, and into which it is forced by the piston. The concave side of the flap is of the same curve as the rim of the case, and when pushed back forms a part of it. Its width is, of course, equal to that of the drum, against the rim of which its lower edge is pressed; this is effected in some pumps by springs, in others by cams, cog-wheels, etc., fixed on the axles, as in the last one.

In Fig. 3519 the abutment is movable. A solid wheel, formed into three spiral wings that act as pistons, is turned round within a cylindrical case. The abutment *B* is a piece of metal whose width is equal to the thickness of the wings, or the interior breadth of the cylinder; it is made to slide through a stuffing-box on the top of the case, and by its weight to descend and rest upon the wings. Its upper part terminates in a rod, which, passing between two rollers, preserves it in a perpendicular position. As the wheel is turned, the point of each wing pushes before it the water that enters the lower part of the cylinder, and drives it through the valve into the ascending pipe *A*; at the same time the abutment is gradually raised by the curved surface of the wing, and as soon as the end of the latter passes under it, the load on the rod causes it instantly to descend upon the next one, which in its turn produces the same effect. This pump is as old as the 16th century, and prob-

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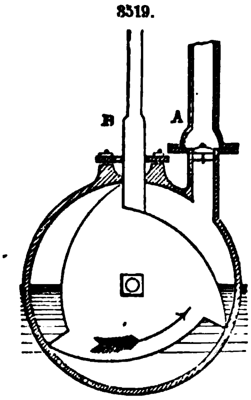
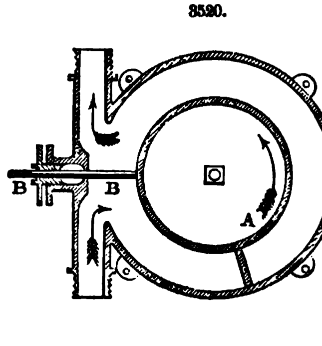


3520.



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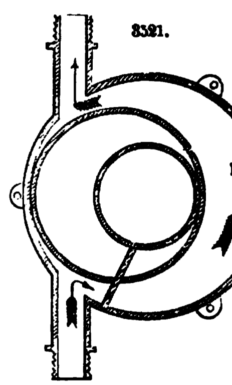

ably was known much earlier. Besides the defects common to most of its species, it has one peculiar to itself: as the abutment must be loaded with weights sufficient to overcome the pressure of the liquid column over the valve (otherwise it would itself be raised and the water would escape beneath it), the power to work this pump is more than double the amount which the water forced up requires. The instrument is interesting, however, as affording an illustration of the early use of the sliding

valve and stuffing-box, and as containing some of the elements of recent rotary pumps and steam-engines.

The pump represented by Fig. 3520 consists also of an exterior case or short cylinder, within which a small and solid one, *A*, is made to revolve. To the last an arm or piston is attached, or cast in one piece with it, the sides and ends of which are fitted to bear slightly against the sides and rim in the case. An abutment *B B* slides backward and forward through a stuffing-box, and is so arranged (by means of a cam or other contrivance connected to the axle of the small cylinder on the outside of the case) that it can be pushed into the interior as in the figure, and at the proper time be drawn back to afford a passage for the piston. Two openings near each other are made through the case on opposite sides of *B B*, and to these the suction and forcing pipes are united. Thus when the piston is moved in the direction of the arrow on the small cylinder, it pushes the water before it, and the vacuity formed behind is instantly filled with fresh portions driven up the suction-pipe by the atmosphere; and when the piston in its course descends past *B B*, it sweeps this water up the same way.

Fig. 3521 represents a pump consisting of two concentric cylinders or drums, the annular space between them forming the pump-chamber; but the inner one, instead of revolving as in the preceding figures, is immovable, being fixed to the sides of the outer one or case. The piston is a rectangular and loose piece of brass or other metal, accurately fitted to occupy and move in the space between the two cylinders. To drive the piston, and at the same time to form an abutment between the orifices of the induction and eduction pipes, a third cylinder is employed, to which a revolving motion is imparted by a crank and axle in the usual way. This cylinder is eccentric to the others, and is of such a diameter and thickness that its interior and exterior surfaces touch the inner and outer cylinders, as represented in the cut, the places of contact preventing water from passing: a slit or groove equal in width to the thickness of the piston is made through its periphery, into which slit the piston is placed. When turned in the direction of the large arrow, the water in the lower part of the pump is swept round and forced up the rising pipe, and the void behind the piston is again filled by water from the reservoir into which the lower pipe is inserted. This machine was originally designed, like most rotary pumps, for a steam-engine; and it is almost unique in the number of times that it has been reinvented.

In others the pistons slide within a revolving cylinder or drum that is concentric with the exterior one. Fig. 3522 is a specimen of a French pump of this kind. The abutment, in the form of a seg-

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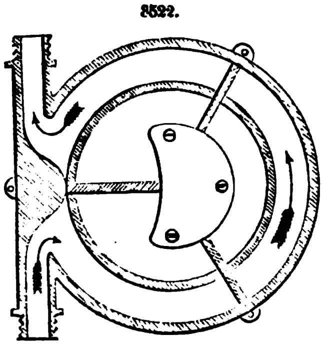
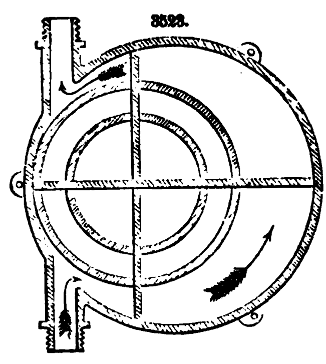


3523.



ment, is secured to the inner circumference of the case, and the drum turns against it at the centre of the chord line; on both sides of the place of contact it is curved to the extremities of the arc, and the sucking and forcing pipes communicate with the pump through it, as represented in the figure. To the centre of one or both ends of the case is screwed fast a thick piece of brass whose outline resembles that of the letter D; the flattened side is placed toward the abutment, and is so formed that the same distance is preserved between it and the opposite parts of the abutment as between its convex surface and the rim of the case. The pistons, as in the last figure, are rectangular pieces of stout metal, and are dropped into slits made through the rim of the drum, their length being equal to that of the case, and their width to the distance between its rim and the D-piece. They are moved by a crank attached to the drum-axle. To lessen the friction and compensate for the wear of the abutment, that part of the latter against which the drum turns is sometimes made hollow; a piece of brass is let into it and pressed against the periphery of the drum by a spring.

In Fig. 3523 the axis of the drum or smaller cylinder is so placed as to cause its periphery to rub against the inner circumference of the case. Two rectangular pistons, whose lengths are equal to the internal diameter of the case, cross each other at right angles, being notched so as to allow them to slide backward and forward to an extent equal to the widest space between the two cylinders. The case of this pump is not perfectly cylindrical, but of such a form that the four ends of the pistons are always in contact with it. An axle on the drum is moved by a crank. Fire-engines have been made on the same principle.

The Compound Propeller-Pump is one of the best modern forms of rotary pump. It consists of a cast-iron pipe, provided at the bottom with a basket-chamber, and at top with an elbow. In the centre of the pipe is a shaft carrying a series of propellers, between which are stationary wings, with a bearing, every 5 feet, the shaft being revolved either by means of a pulley and a belt, or directly by an engine. An ingenious water-bearing, almost frictionless, is applied to the larger

sizes of these propeller-pumps. Fig. 3524 represents its cross-section, and it is thus described by the manufacturers: "It consists of a cast-iron beam, which rests upon the top elbow of the pump, and upon which are secured pillars supporting a stationary disk, provided with an ordinary stuffing-box, through which revolves the propeller-shaft. Under a dome which rests on the stationary disk is another disk, which is secured to the propeller-shaft and revolves with it, and which is provided with an annular piston with ring-packing. Water is forced between the stationary and revolving disks through an ordinary pipe, under a pressure equal to the weight to be sustained per square inch, which is confined between these disks by the annular piston—thus separating them by a film of water upon which the revolving disk floats, sustaining the entire weight of the revolving machinery and most of that of the column of water lifted by the pump. Any surplus water forced between the disks tends to lift the revolving disk higher than a given point, and raise the annular piston off the stationary disk, and thus allow this excess of water to pass out under it, which is received into the dome and returned through a common pipe to the tank from which it was supplied."

3524.

3525.

3526.

Bagley & Sewell's Rotary Pump is represented in Fig. 3525, a vertical longitudinal section, and Fig. 3526, a transverse section. A is the main case, made in one piece, and having attached the ring B, seen in both sections. The space outside of B is the water-space. This cylinder is inclosed by the disk D, which is attached to the shaft. An eccentric ring E is attached to the disk D so that in revolving its outer surface touches the inside of the case A, while the interior surface upon the opposite side of the ring touches the outside of the ring B. The eccentric ring E acts as the piston of the pump. The suction and discharge are respectively shown in both sections at I and J, the direction of the water being indicated in Fig. 3525 by the arrows. The parts are separated by the valve $H\,H$, shown separately at 3, which is moved back and forth on its seat by two tumblers shown in Fig. 3526 between H and H. These tumblers are moved by the eccentric ring E, which passes between them. The centre ring B is made enough deeper than the casing A, as shown in Fig. 3525, to equalize the quantity of water within and without the eccentric piston-ring E. F is the cover or outside case, and contains a closed bearing for the end of the shaft. The inner part of the disk D forms a collar G to the shaft, and by means of a screw at the end this collar can be forced tightly against its seat K, thus avoiding the use of packing. In the centre of the seat there is a circular groove, shown in section at $K\,K$, which connects by a drilled channel with the suction part. Any tendency to escape of water at the seat by pressure is thus overcome by vacuum force.

Centrifugal Pumps.

A centrifugal pump, in its most general form, may be considered as a bent pipe, open at both ends, revolving round a suction-pipe as a centre; the plane of motion being either horizontal or vertical, and the curvature being wholly in the plane of motion. Water, entering the revolving pipe through the suction-pipe, revolves with it, and the result is that it is carried by the centrifugal force outward from the centre. The revolving pipe may be straight, but a curved form is preferable, as will be evident from a consideration of the circumstances affecting the velocity of discharge. Two velocities are to be noticed in this connection: the tangential velocity of the revolving pipe at its outer extremity, and the velocity of water at the exit, which is in the direction of the tangent to the curve of the arm at its extreme end. If the pipe is bent so that its extreme tangent coincides with the tangent to the circle described by it, then the velocity of exit is directly opposed to the tangential velocity; and hence the actual velocity of the water is the difference between the two. The sectional area of the pipe may be uniform or variable, since the pressure per square inch produced by a vertical column is independent of any variation in the section of the column, and dependent only on its height. The height of lift depends only on the tangential velocity of the circumference; every tangential velocity giving a constant height of lift—sometimes termed "head"—whether the pump is small or large. The quantity of water discharged is in proportion to the area of the discharging orifices at the circumference, or in proportion to the square of the diameter, when the breadth is kept the same.

Let Q represent the quantity of water, in cubic feet, to be pumped per minute, h the height of suction in feet, h' the height of discharge in feet, and d the diameter of suction-pipe, equal to the diameter of discharge-pipe, in feet; then, according to Fink (see "Des Ingenieur's Taschenbuch, von dem Verein Hütte"), $d = 0.36\sqrt{\frac{Q}{\sqrt{2g(h+h')}}}$ · g being the acceleration due to gravity, 32.25 feet

If the suction takes place on one side of the wheel, the inside diameter of the wheel is equal to 1.2 d, and the outside to 2.4 d. If the suction takes place at both sides of the wheel, the inside diameter of the wheel is equal to 0.85 d, and the outside to 1.7 d. Then the suction-pipe will have two branches, the area of each equal to half the area of d. The suction-pipe should be as short as possible, to prevent the air from entering the pump. The tangential velocity of the outer edge of wheel, for the delivery Q, is equal to $1.25 \sqrt{2g(h+h')}$.

The arms are six in number, constructed as follows: Divide the central angle of 60°, which incloses the outer ends of the two arms, into any number of equal parts by drawing the radii, and divide the breadth of the wheel in the same manner by drawing concentric circles. The intersections of the several radii with the corresponding circles give points of the arm.

In experiments with Mr. Appold's pump, a velocity of 500 ft. per minute of the circumference raised the water 1 ft. high, and maintained it at that level without discharging any; and a double velocity raised the water to four times the height, as the centrifugal force was proportionate to the square of the velocity; consequently,

500 feet	per minute	raised the water	1 foot	without discharge.
1,000	"	"	"	4 feet	"
2,000	"	"	"	16 "	"
4,000	"	"	"	64 "	"

The greatest height to which the water had been raised without discharge, in the experiments with the 1-foot pump, was 67.7 ft., with a velocity of 4,153 ft. per minute, being rather less than the calculated height, owing probably to leakage with the greater pressure. A velocity of 1,128 ft. per minute raised the water 5¼ ft. without any discharge, and the maximum effect from the power employed in raising to the same height 5¼ ft. was obtained at the velocity of 1,678 ft. per minute, giving a discharge of 1,400 gallons per minute from the 1-foot pump. The additional velocity required to effect the discharge is 550 ft. per minute; or the velocity required to effect a discharge of 1,400 gallons per minute, through a 1-foot pump, working at a dead level without any height of lift, is 550 ft. per minute. Consequently, adding this number in each case to the velocity given above at which no discharge takes place, the following velocities are obtained for the maximum effect to be produced in each case:

1,050 feet	per minute,	velocity	for 1 foot	height of lift.
1,550	"	"	"	4 feet	"
2,550	"	"	"	16 "	"
4,550	"	"	"	64 "	"

Or, in general terms, the velocity in feet per minute for the circumference of the pump to be driven, to raise the water to a certain height, is equal to $550 + (500 \sqrt{\text{height of lift in feet}})$.

When a quick application with a discharge of large quantities of water is the most important consideration for a pump, the centrifugal pump is of great value. There being no valves in action while at work, it will allow large stones to pass, and in fact almost anything that can enter between the arms. In one instance, in putting in the foundation of harbor works at Dover, from 2,000 to 3,000 gallons of water per minute was discharged by one of these pumps. For the drainage of canals at

3397.

Dordrecht, Holland, centrifugal pumps, constructed by Messrs. Gwynne & Co. of England, have been applied. There were three sets of them, of different sizes. The largest had pipes 24 in. in diameter, and was capable of discharging 10,000 gallons per minute; it was driven direct by an engine with a cylinder of 18 in. diameter and 16 in. stroke. The smallest pump had pipes 16 in. in diameter, and

discharged 3,500 gallons per minute, the engine-cylinder being 13 in. in diameter with a stroke of 10 in. All the engines were provided with variable expansion gear, and were worked with 65 lbs. steam cut off at three-sixteenths of the stroke.

Messrs. Easton, Amos & Sons, of England, applied a centrifugal pump to the Trafalgar Square fountains, forcing water to a height of 57 ft. In 1862 a trial was made in England with a centrifugal

3328.

pump constructed by Messrs. Gwynne & Co. (See *The Engineer* for that year.) The pump was 4 ft. in diameter, and was driven by two engines, working at full stroke with 200 revolutions per minute, and giving 154.12 effective horse-power. In the calculation of the above power, it was ascertained that to run the pump without doing work required a pressure of 1¼ lb. per square inch; and one-seventh of the remaining pressure was deducted for the friction due to the load. The water was lifted to 20 ft. 6¼ in. from the level in the lowest tank to the highest point in the upper tank. The

calculated discharge was 3,268 cub. ft. or 91.03 tons of water per minute, which, lifted 20.73 ft., would represent 128.1 horse-power of work done. This would correspond to the high duty of 83.18 per cent. given off by the pump in useful work.

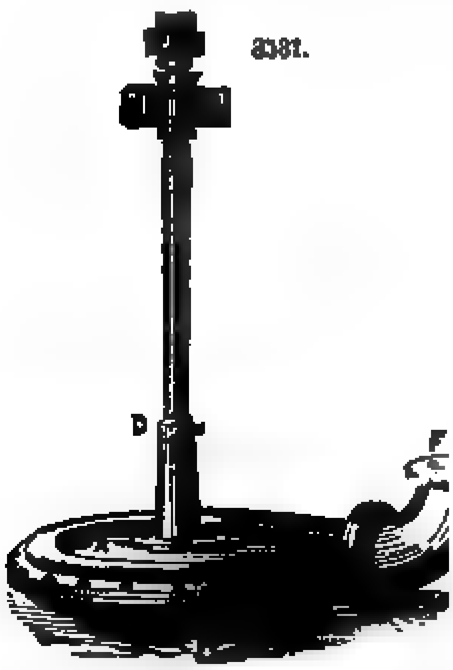
Types of Centrifugal Pumps.—Centrifugal pumps may be either vertical or horizontal—a vertical pump being arranged with the shaft horizontal, and the horizontal pump with the shaft vertical. Good examples of these two varieties are shown in Figs. 3527 and 3528, which represent vertical and horizontal pumps respectively, of German design. The vertical pump, Fig. 3527, is 6.17 in. in diameter, made of wrought iron, and has a suction-pipe 2 in. in diameter. On the extension of the shaft (not shown in the drawing) is a pulley, between two pillow-blocks attached to the same frame. This pump raises 15 cub. ft. of water at a speed of 1,800 to 2,000 revolutions per minute. The horizontal pump, Fig. 3528, constructed by L. Schwartzkopff of Berlin, is 20.5 in. in diameter, and has a suction-pipe of 10.3 in., and a delivery-pipe of 9.25 in. There is a suction-valve at the bottom of the suction-pipe, to prevent the water from running out when the pump stops working, and also a delivery-valve with a screw to regulate its opening, as shown. Running at 500 revolutions, this pump raises 260 cub. ft. of water per minute to a height of 16.46 ft., requiring 11 horse-power to drive it.

The Andrews Centrifugal Pump.—Mr. W. D. Andrews of New York seems to be the first who introduced centrifugal pumps in this country. Fig. 3529 represents a vertical section of the Andrews anti-friction centrifugal pump, and Fig. 3530 the revolving disk with its wings. The wings are straight, in line with the driving-shaft, from one to six in number, their outer edges conforming to the shape of the chamber C, but not quite touching it; they extend beyond the disk K into the passage between cases $D\,D'$. The driving-shaft G passes out through a bearing and stuffing-box on case D', and through a stationary arm R, secured to case D', this arm carries the driving-pulley P, which connects with shaft G by a coupling S and set-screw S'. The pulley, running loose on arm R, is lubricated from a chamber surrounding the shaft within the arm. The centrifugal force exerted by the outer ends of the wings, extending over and beyond the joint between the disk and case, prevents the admission of sand to the bearing, and creates a partial vacuum within the disk. The small openings $k\,k$, connecting the spaces on both sides of the disk, equalize the vacuum, thus dispensing with a thrust-bearing.

3530.

The Heald & Sisco Centrifugal Pumps are illustrated in the accompanying figures. Fig. 3531 has a vertical shaft D, to which the wheel, revolving in the shell A, is attached. The water enters the pump at the bottom, and is discharged at F. This pump should be constantly immersed in the fluid to be raised; it is intended for draining lock-pits, coffer-dams, tan-vats, etc., where water is very foul, containing mud, sand, bark, etc. Fig. 3532 is a pump driven directly by an oscillating engine. D is the steam-induction pipe; E, the eduction pipe; A, the valve-chamber on the cylinder, the rolling valve within it being worked by an eccentric from the engine-shaft. The guides for relieving the strain on the piston-rod project from the head of the cylinder, and are partially concealed by the counterbalance wheels $J\,J$; but the end-piece G is seen between the wheels. F is the force-pump, used for priming the main pump B, through the pipes $I\,H$. It is operated by means of friction-wheels connected or discon-

nected by a lever, while the engine is running slowly. *C C* are swiveled elbows for suction and discharge. The chains show one mode of securing the machine to the deck of a wrecking vessel.


3531.

A large pump constructed by the same makers is represented in Fig. 3533. It is 6 ft. in diameter, and has six arms with openings of 6 × 7 in., a 44-in. suction-pipe, and 32-in. discharge-pipe; it is rated at 35,000 gallons per minute. An engine to work this pump directly, for a small lift, has a cylinder of 24 in. diameter and 16 in. stroke, running at a speed of 135 revolutions per minute.

3534. 3535.

Fig. 3534 is a hollow-arm and Fig. 3535 a solid-arm wheel, as used on the Heald & Sisco pumps. The solid-arm wheel is used when the fluid contains stringy or tenacious matters; the hollow-arm

3536. 3537.

wheel is preferable for general use, the water not being thrashed by the arms, but forced steadily toward the discharge.

Trials of Centrifugal Pumps.—The following table gives the results of a trial of the centrifugal

pumps above described, made at the American Institute Fair in 1872. The principal dimensions of the pumps were as follows:

	Andrews.	Heald & Sisco.*
Diameter of wheel, in.	26	30.5
" of suction-pipe, in.	9¾	12
" of discharge-pipe, in.	9⅛	10
" of mouth-pin, in.	15$\frac{5}{16}$	..

The power required to drive the pumps was measured by a transmitting dynamometer on the driving-shaft, and the actual delivery of water was also measured.

William D. Andrews's Pump, tested November 13, 1872.

NUMBER OF TEST.	Revolutions per Minute.	Gallons discharged per Minute.	Height of Discharge in Feet.	Work done in Horse-power.	Dynamometers, Horse-power.	Per Cent. of Efficiency.
1	191.9	1518.12	12.25	4.69	10.09	46.52
2	195.5	2023.82	12.62	6.47	12.2	53.0
3	200.5	2499.33	13.08	8.28	14.38	57.57
Heald & Sisco Pump, tested November 16, 1872.						
1	188.3	1678.87	12.38	5.22	8.11	64.50
2	202.7	2044.9	12.58	6.51	10.74	60.74
3	213.7	2371.67	13.0	7.81	14.02	55.72

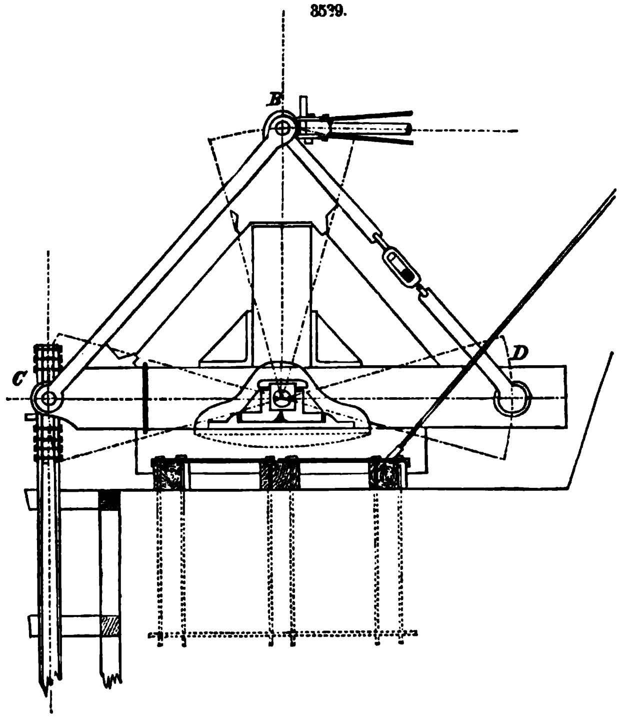
MINING PUMPS.

When permanent works are put into a mine, pumps are substituted for water-buckets. The first is the lift or sinking pump, which is lowered as the shaft is deepened, and the suction-pipe rests on the sump. It is represented in Fig. 3536. *A* is the barrel; *B*, bucket; *C*, rod; *G*, column-pipe, made up of lap-welded tubes, ¼ in. thick, and always 2 in. greater in diameter than the bore of the pump. These pumps are usually 12 in. in diameter and 20 ft. long.

In inclined shafts, a jackhead pump, Fig. 3537, is used for sinking. Here the column *A* and clack-chamber *E* are bolted on the branch *B* of the barrel *C*, and the pump-rod passes through a stuffing-box *D*, on the top of the barrel.

When the shaft has reached the depth of 225 ft., a chamber is cut into the side of the shaft for a tank to receive the water from the sinking-pump, and a plunger-pump, Fig. 3538, is permanently placed there to elevate the water to the surface. The sinking-pump, as before, follows the shaft down, and when an additional depth of 225 ft. has been reached, another tank and plunger-pump are put in; and so on. In Fig. 3538, *A* is the plunger; *B*, barrel; *C*, clack-chamber; *D D*, valves; *E*, suction. All the pumps of a shaft are attached to one pump-rod, of heavy timbers, strengthened with iron plates and bolts; this rod receives a reciprocating vertical motion from an engine, by means of a bob or three-armed lever, as shown in Fig. 3539. *A* is the fulcrum; *B*, pitman to the bob; *C*, pump-rod. A weight is placed at *D* to balance the pump-rod.

3539.



Every 450 ft. a balance-bob, consisting of a two-armed lever, is attached to the pump-rod at one end, and carries a weight on the other. When the shaft changes its direction, a second pump-rod is attached to the first by means of a V-bob, as shown in Fig. 3540. *A A* are pins for connection with first rod; *B*, bearing for second rod; *C*, fulcrum. The line *A C* is horizontal when at centre of motion.

Fig. 3541 represents a Cornish pump on a larger scale. It has a 12-in. steam-cylinder and 8-in. water-cylinder, with 48 in. stroke, is intended for 150 to 175 ft. of lift, and makes about 20 double

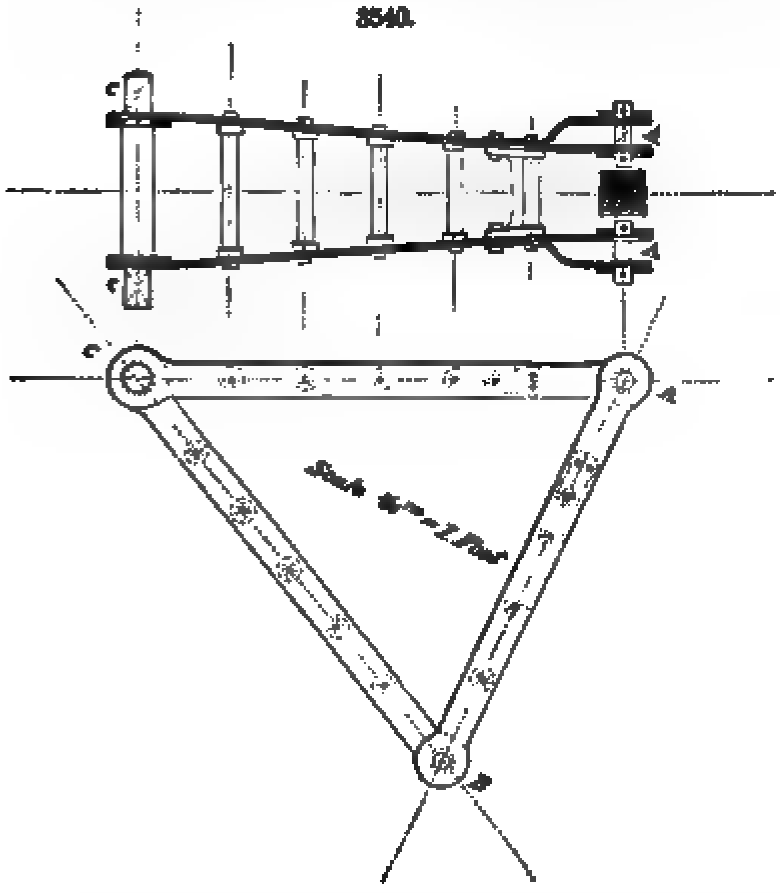
* Four curved hollow arms, each 4 × 3½ in.

strokes per minute. Its steam-valve arrangement is the same as on the Knowles steam-pump (see PUMPS, STEAM), but it can be made single-acting by shutting off the steam from one end of the cylinder.

VACUUM-PUMPS.—Pumps of this variety, in which the steam and water are in direct contact during action, were among the earliest forms of steam-pumping engines. Their simplicity and cheapness are great recommendations to favor, and their efficiency seems to differ but little from that of direct-acting steam-pumps.

The Pulsometer is a steam-pump, which dispenses with all movable parts except the valves. Fig. 3542 represents a sectional view of a pulsometer, as manufactured by the Pulsometer Steam-Pump Company at Jersey City, N. J. It consists of two bottle-shaped chambers *A A*, joined together side by side, with tapering necks bent toward each other, and uniting in a common upright passage to which the steam-pipe is attached. A small ball *C* is fitted so as to oscillate with a slight rolling motion between seats formed in the junction of the two chambers, which are alternately opened and closed for the admission of steam. Each chamber communicates by means of a separate suction-valve, *E E*, with the common vertical induction-passage *D*. *I I* are valve-guards to prevent the valves from opening too far. Each chamber communicates, by means of delivery-valves similar in construction to the suction-valves, with the common delivery-passage *H*. *J* is the air-chamber, cast between the necks of chambers *A A*, which con-

3540.



nects only with the induction-passage *D*. A small brass air-check valve is screwed into the neck of each chamber *A A*, and one into the vacuum-chamber *J*, so that their stems hang downward. The check-valve in the neck of each chamber *A A* allows a small quantity of air to enter above the water, to prevent the steam from agitating it on its first entrance, and to diminish the condensation of steam during the discharge stroke. The check-valve in the vacuum-chamber *J* serves to cushion the blow of the water consequent upon the filling of each chamber alternately.

The action of the pulsometer is as follows: When all chambers and pipes are empty, the air-check valves have to be closed, and the globe valve opened for an instant; then steam will enter one of the chambers, expel the air, and condense, forming a vacuum. This operation being repeated several times, both chambers will be filled with water through the induction-pipe. Each air-valve in the chambers must now be opened a little, to secure a regular and continuous action, which will be recognized by the steady pulsation and smooth working of the steam-ball without a rattle. Steam, being now permanently admitted, enters the chamber not closed by the ball, and forces out the water through the discharge-valves, until its surface is lowered below the discharge-orifice. At that instant the steam begins to escape into the discharge-pipe, and condense; thus a partial vacuum is formed in the chamber. The water in the other chamber now presses the ball, which rolls over and closes the first chamber, where water enters through the induction-valves to fill the vacuum. The operation alternately changes from one chamber to the other. One chamber fills with water in about

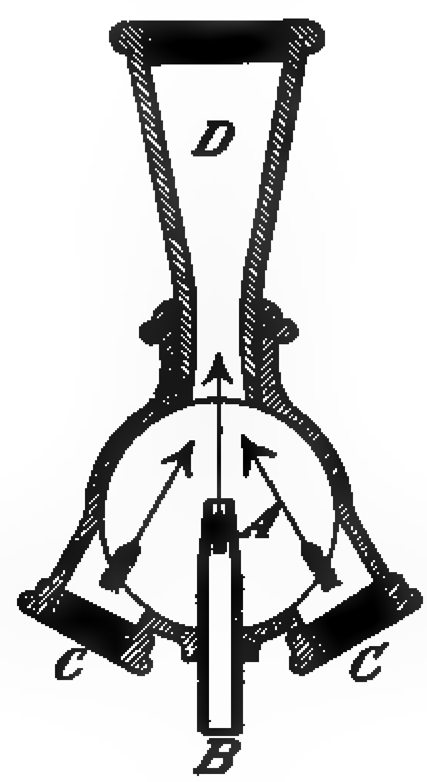
two-thirds of the time required for the other to empty. As soon as it is full, a drop of water issues from the air-valve which had previously been admitting air into the chamber.

Some interesting details are added, from a report of a trial of the pulsometer by Theron Skeel, published in the *Engineering and Mining Journal*, xxii., 407. The pulsometer had an 8-in. induction-pipe connected with a well in the cellar, and a 4-in. discharge-pipe connected with a tank on the roof of the building. From this tank the water fell through a "drowned weir" into the well in the cellar. The steam used was drawn from a boiler 80 ft. distant through a 2-in. steam-pipe covered with asbestos felting. The test lasted 2 hours and 3 minutes, during which time the mean steam-pressure in the boiler was 76.6 lbs.; mean steam-pressure beyond the throttle-valve, 20.5 lbs; mean water-pressure, 18.8 lbs.; average number of single strokes per minute, 46.3; mean temperature of injection-water, 67.5°; mean temperature of discharge-water, 76.5°; mean temperature of feed-water, 38.5°; temperature of the outside air, 30°; temperature in the room, 40°. The experiment showed that the pulsometer delivered on the average 1,283½ cub. ft. (equivalent to 9,626 gallons) of water per hour. The weight of steam used by the pulsometer was 579 lbs. per hour; the weight of coal consumed during the experiment was 67.5 lbs. The duty, equivalent to 1,283.5 cub. ft. of water having a temperature of 76° and weighing 53 lbs. per cub. ft. (it contained about 15 per cent. of air), raised 62½ ft. by 67½ lbs. of coal, is 1,283.5 × 53 × 62.5 × 100 ÷ 67.5 = 7½ millions.

The Steam Siphon Pump is the simplest of all pumps, having no movable parts whatever. Fig. 8543 represents a cross-section of Landsdell's patent steam siphon pump. *A* is the body; *B*, steam-pipe; *C C*, suction-pipe; and *D*, discharge-pipe. Steam, being admitted through the pipe *B*, rushes across the globular chamber *A* into the discharge-pipe *D*, and carries with it the air, thus forming a

8542.

8543.



vacuum, drawing the water through the suction-pipes *C C*, and forcing it outward through *D* with a velocity proportioned to the pressure of steam in the boiler. These pumps are extensively used as bilge-pumps. R. H. B.*

PUMPS, STEAM. Under this heading reference is made to pumps and engines rigidly connected together, in distinction to power pumps which are moved by gearing or flexible connections.

Mr. H. R. Worthington of New York, who is probably the pioneer inventor of a direct-acting steam-pump, about the year 1840, being engaged in experiments with a steamboat for canal navigation, invented an independent steam-pump for feeding marine boilers, which he patented in 1844. In this pump the steam-cylinder was supplied with steam through a pipe, which had a valve at the other end within the boiler. This valve was controlled by a float, which by its rising or falling supplied more or less steam, and allowed the pump to run faster or slower, according to the height of the water. The slide-valve controlling the admission of steam to the cylinder was acted upon by a spring, compressed by the action of the engine, so that it remained at rest until, at the proper time, by the further motion of the engine, the spring was released and moved the valve. This was the beginning of the numerous class of inventions that followed for storing power to act upon the steam-valve. In some an application was made of the force of gravity, the moving piston being caused to lift a weight which, passing a neutral point or centre at the instant of piston stoppage, acted on the valve. The momentum of the piston has also been applied as the force to move the valve, and a pump on this principle was patented in 1849 by Messrs. Worthington & Baker.

* Prepared by T. F. Krajewski, under the direction of R. H. Buel.

The Worthington & Baker Pump, Figs. 3544 and 3545, has been extensively used as an independent feed-pump for marine and stationary boilers. The general principle involved in its construction is the combination of a pump with the steam-cylinder that drives it by direct action, without the intervention of a crank, fly-wheel, or any other device for producing rotary motion. The steam-cylinder S is in all respects similar to that of an ordinary high-pressure engine, with the parts as usually constructed for the admission and emission of the steam. The rod of the piston which traverses in this cylinder is prolonged and attached to the plunger P of a double-acting pump. The arm A is fastened to the middle of the piston-rod, and strikes the tappets or nuts on the valve-rod at each end of the stroke, in order to change the position of the steam-valve, and admit steam to alternate sides of the piston. At low speed, more especially, the obvious tendency of the motion is to bring the steam-valve directly over the ports, and exclude the steam from either end of the cylinder. The patentees obviated this serious difficulty in a manner at once simple and effective. By a peculiar arrangement of the water-passages in the pump, the resistance is reduced or relieved at or near the end of the stroke, and thus a momentum is suddenly generated amply sufficient to throw the valve wide open. A modification of the ordinary slide-valve, which the patentees denominate a B valve, is shown in the drawing, and serves to admit the steam in the proper direction, without resorting to levers for changing the motion. The pump shown at C, called the *double-acting plunger-pump*, consists of a plunger or plug P, working through a ring, which may be made adjustable if necessary. The course of the water, as indicated by the arrows, is through a set of valves resting upon seats that radiate from a common centre, and covered in by the cap A, Fig. 3545, which is held firmly in its place by the single bolt B. As all these valves are thus accessible at a moment's warning, a great source of danger from delay in relieving them from impediments is avoided.

The next step taken in the improvement of the direct-acting steam pump was to act on the valve by means of a secondary or sub-cylinder and piston, to which steam was admitted by a sub-valve, actuated by the main piston at the end of the stroke. This is the plan now most extensively used, the numerous variations and modifications of which have not changed its general character. Finally,

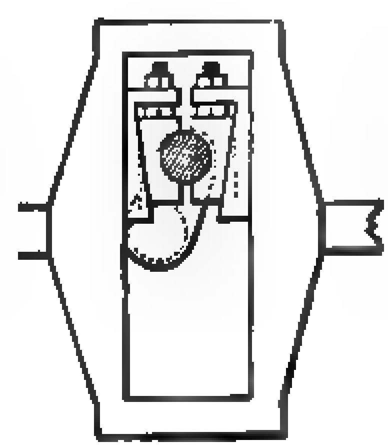
there is the steam-pump built on the general principles of the rotative steam-engine, with a crank and fly-wheel, and an eccentric to operate the valve, or a fly-wheel with yoke arrangements to control the movement of the piston and valve.

Forms of Steam-Pumps.—Steam-pumps are made with single steam-cylinder, non-expanding, and with two cylinders on the compound or double-cylinder principle. Direct-acting pumps can be divided into two classes: steam-pumps with outside valve-gear, or those having some of the moving parts, which act to operate the valve, outside of the cylinder; and steam-pumps having their valve-gear inside, no moving parts being visible when the pump is in operation, except the piston-rod. Pumps with crank and fly-wheel form a separate class, and the general divisions of this class can be illustrated by two examples.

The Eclipse Steam-Pump.—Fig. 3546 represents the Eclipse steam-pump, manufactured by S. D. Hubbard & Co. in Pittsburgh, Pa. The crank-shaft is here on the outside of the steam-cylinder, with an eccentric acting on a rocking lever, which is connected with a common slide-valve controlling the admission and exhaust of steam. On each end of the shaft is a fly-wheel with a crank-pin, to which motion is imparted from the cross-head through the connecting-rods, the cross-head moving the piston and plunger-rod. The movement of the valve is thus positive, and the speed of the piston and plunger varies during the stroke, as in a common steam-engine, according to the distance from the end of the stroke.

The Clayton Steam-Pump.—Fig. 3547 represents another crank-wheel pump, as manufactured by James Clayton of Brooklyn, N. Y. In a yoke, shown separately in Fig. 3548, which couples the piston- and plunger-rods, is a bearing for the crank-shaft journal, which performs here the same function as the crank-pin of the former pump. This bearing slides up and down in the yoke, the lost

3548.



motion caused by the wear being taken up by the adjusting wedges shown. On both sides of this journal are two arms: one supports the fly-wheel, which is attached to it in the centre of the motion; the other gives movement to a similar but smaller yoke, which acts on the steam-valve.

In this class of steam-pumps, the matter of properly arresting the piston motion does not present any difficulties, the piston being controlled by a crank; but in the case of direct-acting steam-pumps this is a serious consideration, and has given rise to numerous inventions. The difficulty to be overcome consists in arresting the motion of the piston at a proper distance from the cylinder-head, whether the piston moves at a slow or a high speed. It is easy to see that, although the motion of the piston is controlled for a certain speed, if this speed is exceeded the increased momentum may carry the piston beyond a proper limit, and endanger the cylinder-heads; while in the reverse case the stroke of the piston may be shortened, thus occasioning a waste of steam. The principal efforts in the way of remedy may be said to consist of a prompt admission of steam at the end of the stroke, buffers placed between the cylinder-covers and the piston, and the early closure of exhaust, producing a steam-cushion. This last plan, which is most generally applied, is effected either by the closing of the exhaust-port by the piston, or by the action of the main valve. The same plan of cushioning is also applied to the sub-pistons which operate the valve.

Examples of the class of steam-pumps which have no moving parts seen on the outside are given below.

The Cameron Steam-Pump.—Fig. 3549 represents a sectional view of the Cameron steam-pump. *A* is the steam-cylinder; *C*, steam-piston; *D*, piston-rod; *L*, steam-chest; *F*, auxiliary piston; *G*, slide-valve; *H*, starting bar connected with a handle on the outside; *I*, *I*, reversing valves, and *K*, *K*, bonnets over them; *N*, the body-piece connecting the steam- and water-cylinders; *B*, water-cylinder, with the valve-chest bonnet removed; *M*, a valve-seat and valve shown in section; *T*, discharge air-chamber. Steam enters the steam-chest between the two heads of the auxiliary piston *F*, which

carries with it the slide-valve *G*. Minute openings are made in the heads of the piston *F*, to permit a leakage of steam from the steam-chest proper to the spaces inclosed by these heads and the steam-

chest cover. When the piston reaches the end of the stroke, it strikes the small valve *I*, which opens the communication between the space at that end of the auxiliary piston and the exhaust-pipe through the passage *E*. At that moment the auxiliary piston moves, the pressure being only on one of its faces; thus the position of the slide-valve is reversed, and the steam-

of their valve-gear external are more numerous than the preceding class, and illustrations of several varieties are appended.

The Worthington Duplex Pump.—Fig. 3550 represents the Worthington duplex pump. Two

steam-pumps are placed side by side, and so combined as to act reciprocally upon the steam-valves of each other, by means of rocking shafts; one arm of each rocker receiving its motion from the piston-rod of one pump, and imparting this motion to the steam-valve of the other pump by the second arm. The action of this pump is exactly the same as that of the Worthington duplex pumping engine (see PUMPING ENGINES), except that here there is only one high-pressure cylinder. The means of cushioning the momentum of the piston is as follows: There are two ports for each end of the steam-cylinders, both of which are exhaust-ports, but only the outside one is an admission-port. The piston, arriving at the end of the stroke, covers the inside port only, the outside port being covered by the steam-valve, and thus the steam, being compressed, checks the movement of the piston. On large pumps, as a precaution against accident—as for instance a sudden suppression of the resistance by breaking of the pipes—a special steam-valve, or steam-buffer, is placed on the cylinder-cover; so that should the piston exceed the proper limit of its stroke, it strikes this valve and thus admits steam to the cylinder. This valve is kept closed at other times by the steam.

The Knowles Steam-Pump.—Figs. 3551 and 3552 represent the Knowles steam-pump. Its valve-gear consists of an auxiliary piston-valve, or chest-piston, which imparts the motion to the main valve. This chest-piston has both reciprocating and rotary motion; the rotary motion being imparted to it by means of a rocking lever attached to the frame, one end of which is attached by a connecting-rod to the chest-piston rod, in such a manner that, when the end of the rocking lever moves up or down, the short piston partially rotates. The rocking lever receives its motion from the main-piston rod, which slides under its concave surface, and alternately raises the respective ends. The chest-piston, Fig. 3551, has small ports in its solid part, which communicate at certain times with the steam-chest proper through ports in its lower seat (shown on the right-hand side of the cut, partly in section).

The communication between these ports is established or broken off by rotating the chest-piston. When the main piston is at the end of its stroke, the chest-piston, by the rocking shaft, is placed in the position in which the ports above described communicate, and steam, entering the space between the chest-piston and the steam-chest cover, forces the chest-piston to reciprocate far enough to open the small exhaust-port (shown in the cut in dotted lines), and permit the discharge of steam. This exhaust-port is closed by the chest-piston on its return stroke, and thus a compression takes place in the space, giving the cushion for neutralizing the momentum of the chest-piston. The stroke of the pump can be changed by raising or lowering the arm which slides under the rocking lever, by means of a nut. The upright arm attached to the main piston is an auxiliary arrangement used sometimes when a pump has been at rest long enough to permit the accumulation of rust on the chest-piston, to move the valve by striking the tappets on the chest-piston rod. The main valve is a so-called B-shaped valve, first used on steam-pumps by Mr. Worthington; its action is exactly the reverse of that of the D-valve. The main piston, before it reaches the end of the stroke, closes the exhaust-port (as seen in the cut), and thus compresses the steam that fills the remaining space, and cushions the momentum of the piston. To compensate for the difference in the momentum at different speeds, there is a port connecting the end space of the cylinder with the exhaust-port, and a valve operated from the outside to regulate the area of opening of this port; by closing or opening this valve more or less compression is allowed. There is still another auxiliary port, connecting the end space of the cylinder with the steam-chest, which, being opened by the main valve in time, admits steam to start the piston for its return stroke; and, in case the pump has a condenser attached to it, it gives the cushion for the piston. The steam, after moving the piston, is ordinarily exhausted into the atmosphere; but sometimes it is discharged into a condenser, creating a vacuum on the exhaust side of the steam-piston.

A large double-acting steam-pump, constructed according to the system just described, was built by the Knowles Steam-Pump Works for the Newport water-works; capacity about 1,500,000 U. S. gallons per day, running at the rate of 50 strokes per minute. This pump is on the compound principle, and the following are the most important dimensions: Diameter of high-pressure cylinder, 20 in.; low-pressure cylinder, 38 in.; pump-plungers, 18 in.; stroke, 36 in.; suction- and discharge-pipes, 16 in.; steam pipe, 4 in.; connecting-pipe between cylinders, 6 in.; exhaust-pipe, 8 in.; heater, 10 ft. long, 14 in. diameter, with coil of 1¼-in. pipe for feed-water; steam-cylinders jacketed on sides and heads; area of pump-valves, 864 sq. in.; steam-cylinder of vacuum-pump, 8 in. in diameter; vacuum-cylinder, 14 in., stroke 16 in.; jet-condenser, 23 in. in diameter, 45½ in. high, 2-in. injection-pipe, 6-in. discharge-pipe, 6-in. pipe from condenser to pump.

Blake's Steam-Pump, Figs. 3553 to 3556.—In this the main and auxiliary valves are plain flat slide-valves. The auxiliary valve, being simply a continuation of the three ports of the main cylinder, is also called the movable valve-seat; it receives its motion from the main piston, its valve-rods being connected by levers with the tappet-rods, as shown. On the movable valve-seat, the main (D-shaped) valve is shifted by auxiliary steam-pistons, which move in cylinders forming the end portions of the steam-chest. Fig. 3555 is the plan of the top of the main cylinder, or the seat for the auxiliary valve. The ports $D\ L\ F$ lead to the main cylinder. The ports $E\ E$ admit steam to the auxiliary cylinders, and their course is shown in section on the right-hand side of Fig. 3554; they are opened and closed alternately by the auxiliary valve, the under side of which is shown in Fig. 3556. Between the two auxiliary steam-ports is the port N, Figs. 3554 and 3555, which is the steam-supply port for the steam-chest. Ports $K\ K$, in Fig. 3555, are the exhaust-ports for the auxiliary cylinders, their course being

3556. 3553.

shown in the section on the left-hand side of Fig. 3554; they are put in communication with the port B (shown in Fig. 3555 in the centre between them), which leads to the main exhaust-port, by means of a B-valve, cast in one piece with the auxiliary valve, as seen in Fig. 3556. The ports $A\ B\ C$ are the continuation of the ports in the main cylinder. From this description of the single parts, the working of the pump will be easily understood. Suppose the main piston is moving from left to right; near the end of its stroke it strikes the tappet-rod, and slides the movable valve-seat to the right, thus opening the steam-port on the right and giving lead, and at the same time setting the port on the left in communication with the exhaust. The lead neutralizes the momentum of the main piston, and starts it on the return stroke. The movable seat has opened the auxiliary steam-port E, on the right, thus admitting steam to the auxiliary cylinder on the right and moving the auxiliary piston to the left; the auxiliary exhaust-port K, on the left, is at the same time put in communication with the port B (Fig. 3555) leading to the exhaust-pipe. The momentum of the auxiliary piston is neutralized by the piston overrunning the exhaust-port in time, and thus compressing the remaining steam. This operation is repeated at the other end of the stroke.

The National Steam-Pump, Fig. 3557.—The valve-gear consists of a main piston-valve performing with its ends, or faces, the function of an auxiliary piston, the valve-stem acting as an auxiliary valve. The steam-chest is also an auxiliary cylinder as shown. The valve-stem has some lost motion before it can strike the springs, secured at each end of the valve between a counter-bore and a collar screwed to a shoulder, and thus move the valve. By this arrangement steam can enter and be discharged from the auxiliary cylinder before the valve is moved by the steam, there being slots cut in the stem and combined with passages in the valve-chest covers. On the main valve are grooves by which a communication between the main-cylinder ports and the steam- or exhaust-pipes can be es-

tablished or shut off. The arrows in the figure show the passage of steam into the main cylinder on the right-hand side, and the exhaust on the other side. When the piston arrives at the end of the stroke, the arm on its rod strikes the tappet of the valve-stem and admits steam to the auxiliary cylinder at one end, exhausting it from the other. Thus the valve admits and exhausts steam from the opposite ends of the main cylinder, its momentum being taken up by the spring, which remains compressed until the return stroke.

The Isochronal Steam-Pump, Fig. 3558, so called by its inventors and manufacturers, Messrs. Cope & Maxwell of Hamilton, Ohio, has a governor, the function of which is to regulate the strokes of the piston so as to make them isochronous, or constant in time. These pumps are usually constructed upon the compound principle, but in the engraving one with high-pressure cylinder only, being more suitable for description, is represented, only the steam-cylinder with its valve-gear being shown. The steam-chest consists of a sub-cylinder *E E'*, with two pistons *D' D*, joined together and with the main valve. The sub-cylinder has its own steam-chest and a valve *F*, which admits steam to the sub-cylinder, and thus moves the sub-pistons and the main valve. *H* is a cylinder filled with oil, in which a piston *G* can reciprocate. A channel or port leads from one side of the piston *G* to the other, and is provided with a stop-cock *L*, which when wide open allows the piston to be moved at any speed, as the oil is easily displaced; but when the cock is partially closed, the displacement of the oil will require a certain time. The oil-piston is attached by a rod to the auxiliary steam-pistons, and the latter can thus open the main valve only by consuming a certain time, dependent on the position of the stop-cock. The movement of the oil-cylinder is positive, being imparted from the main

piston-rod by means of the levers $F' I T$. The tappets *e e* of the stem F' are struck by the oil-cylinder, thus moving the valve F, which admits steam to one end of the sub-cylinder and exhausts it from the other. Supposing now the main piston B to be at one end of its stroke (as shown), the valve F is then open and admits steam to the sub-cylinder at E', exhausting it at E; if the stop-cock L were now fully opened, the main valve would be suddenly shot open, admitting the full force of the steam to the piston, instead of allowing the piston to rest for a time, and then have its inertia overcome gradually. As the movement of the sub-pistons is controlled by the piston G, which in turn is controlled by the oil in the cylinder H, the sub-pistons will have to move gradually; the main valve, having a lap, allows sufficient time for the piston to pause, and then furnishes it with steam. The main piston now commences its travel, and moves the oil-cylinder in the opposite direction. The main valve is held open by steam in the sub-cylinder, just balanced by the resistance of the oil in the oil-cylinder. If for any reason the main piston increases its velocity, the oil, resisting a greater velocity of flow, will increase in pressure, and thus, preponderating over the steam-pressure which keeps the main valve open, will partially close that valve. If, on the other hand, the main piston moves more slowly, the oil loses some of its power of resistance, and the steam in the sub-cylinder, preponderating, partially opens the main valve. When the oil-cylinder moves far enough for its end to strike the piston G, it will move the main piston sufficiently to close the exhaust-port, and thus cushion the steam; at this instant the valve F admits steam to the sub-piston.

3559.

Condenser for Steam-Pumps.—A condenser designed for use in connection with steam-pumps, patented by Craig & Brevoort of New York, is shown in Fig. 3559. The flange D is screwed to the suction-orifice of the pump, and the flange S to the pipe leading to the well, or whatever source of supply the pump may have. W is a water-jacket surrounding the main chamber of the condenser B, and with which the suction-pipe S communicates, permitting a free circulation of the water within the jacket and into a hollow cover or top, through a series of openings, one of which is shown at a, and from thence into the body of the condenser B, through the pipe carried by the float F; the pipe also acts automatically as a valve to enlarge or contract the space through which the water enters, by which means the possibility of the condenser being flooded is avoided. The pipe also acts, it will be observed, as a guide to the float F. The valve c, which is raised or lowered by means of a screwed stem, shown coming through the elbow, is for the purpose of increasing or decreasing the flow of water according to the capacity of the pump to which it is attached. The exhaust-pipe from the steam-cylinder is screwed to the cover at E. The exhaust-steam is thus thrown directly into contact with the water entering the condenser on its way to the water-cylinder of the pump through D.

Experiments on Steam-Pumps.—Some experiments on the performance of steam-pumps were made at the Fair of the American Institute in 1867, and a summary of the results is given below.

Summary of Trial of Steam-Pumps at American Institute Fair, 1867. *Steam-Pressure* 60 *lbs. per sq. in.; Water-Pressure the same.*

NAME OF PUMP.	DESCRIPTION OF PUMP.	Length of Stroke.	Diameter of Steam-Cylinder.	Diameter of Water-Cylinder.	Time of Trial.		Number of Double Strokes per Minute.	Indicated Horse-Power.	Effective Horse-Power.	Per Cent. of Efficiency.	Gallons of Water delivered per Minute.	Ratio of Actual Delivery to Displacement of Pump-Plunger.
		Inches.	Inches.	Inches.	Min.	Sec.						
Niagara....	Direct-acting	12 6	12	7	28	40	47 7	12.16	6 36	52.28	181 7	.96
Knowles...	" "	11.8	10	6	25	20	50 1	11.71	5 2	44 35	148 5	.936
Woodward	Crank,.... ..	6	12	7	28	10	95 9	13.41	5.62	48.4	166 8	.865
Niagara ...	"	7	9	5	39	01	111.3	9.65	3 65	37 87	104 4	.954
Clayton....	"	7.5	9	5	36	40	110 6	10.38	1.9	18 38	54 4	.49

The report of the trial of the circulating pumps of the U. S. steamer Tennessee, by Messrs. Skeel and Hunt, published in the *Journal of the Franklin Institute* for December, 1874, and January, 1875, is of unusual interest and value. A synopsis of the report is appended. The pumps were Blake

pumps, similar to that described on page 619. The principal dimensions were as follows: Diameter of steam- and water-cylinders, each 18 in.; diameter of piston-rod, $2\frac{1}{8}$ in.; steam-ports, 5 in. × $1\frac{1}{2}$ in.; exhaust-port, 5 in. × $2\frac{1}{2}$ in.; maximum stroke of piston, $19\frac{3}{4}$ in.; actual stroke of piston, $18\frac{3}{4}$ in.; width of opening of steam-valve, $\frac{3}{8}$ in.; width of opening of exhaust-valve, $\frac{3}{8}$ in.; diameter of auxiliary piston, 5 in.; stroke of the same, $\frac{3}{4}$ in.; 6 receiving and 6 delivery valves, each 7 in. in diameter; total area of valve openings, 171 sq. in.; ratio of piston area, $\frac{2}{3}$; diameter of receiving and discharge nozzles, 15 in.; distance of centre of pump below water-line, 2 ft. 6 in.; length of pump over all, 7 ft.; width over all, 2 ft. 10 in.; height over all, 5 ft. There were two of these pumps used for circulating the water through the condenser; each had a separate suction-pipe, drawing water through a strainer containing 2,000 $\frac{1}{8}$-in. holes, in the bilge of the ship, thence to a Kingston valve, and through 15 ft. of 15-in. copper pipe to the top of condenser, where the water from both pumps united and passed four times through nests of condenser pipes, and finally through two 15-in. copper pipes, 25 ft. long, to outboard delivery valves, 24 in. below the surface of the water. On the occasion of the trial, temporary pipes were attached to each outboard delivery, to carry the water up to a tank where it could be measured. The bottom of the tank was a composition plate, planed, 1 in. thick, with 55 holes, each of $1\frac{1}{8}$ in. diameter, and beveled out on the upper side $\frac{1}{2}$ in. with 30° angle. The average distance of these holes was $3\frac{1}{8}$ in. between the centres. During the experiment a portion of the holes were plugged, and the pumps worked under the additional load due to 11 ft. head on the stand-pipe and the friction of the sides and bends. The volume of water that would be discharged through the plate in the bottom of the tank, at various heads and with different numbers of the orifices plugged up, was first determined; then a series of experiments were made to ascertain the volume of water delivered at various velocities of the pumps, and the power required to work them. These experiments were made by running one pump at a velocity required to maintain a constant head in the tank of nearly 5 ft., the engineer changing the throttle a little, in response to signals, when the head of water varied. The head could be maintained within 2 in. of the desired point. All experiments were made with the same head in the tank, plugging more or less of the holes, in order to change the velocity of the pump in different experiments. In some of the experiments the pumps were run one hour, but as the head and strokes were so nearly constant, half an hour was considered generally sufficient. The number of strokes during a minute was counted every 5 minutes by a correct sand-glass in the long runs, and every $2\frac{1}{2}$ minutes in the short runs; the mean head was noted during the minute, when there was any variation; and indicator cards from steam- and water-cylinders of the forward pump were taken every 5 minutes. The stroke of the forward pump was $18\frac{3}{4}$ in. The following table gives the means of the results:

Table showing Results of Experiments on Circulating Pumps of U. S. Steamer Tennessee, by Messrs. Skeel and Hunt.

DETAILS.	FIRST EXPERIMENT.		SECOND EXPERIMENT.		THIRD EXPERIMENT.	
	Forward Pump.	After Pump.	Forward Pump.	After Pump.	Forward Pump.	After Pump.
Number of strokes	63.46	64.5	79.648	85.458	95.8	99.2
Head of water in tank, inches	61.115	60.75	59.8	61.041	61	60.9
Number of holes open	30	30	40	40	48	48
Cubic feet of water per hour	10,580	10,572	18,884	14,008	16,·28	16,827
Normal volume of pump	10,980	11,110	18,715	14,720	16,500	17,060
Per cent. of do. delivered	96.4	95.2	101.2	95.8	102	98.5
Actual volume of pump	10,510	......	18,190	......	15,870	......
Per cent. of do. delivered	100.2	......	105	......	106.2	......

The fact that the pump actually delivered more water than was due to the piston displacement was explained as follows: In place of having to suck the water from a tank, the pump-cylinder was $2\frac{1}{2}$ ft. below the surface of the water, which would, if the piston were at rest, fill the barrel, and rise $2\frac{1}{2}$ ft. above. The maximum velocity of the water in the suction-pipe was 4 ft. per second, while the velocity due to a head of $2\frac{1}{2}$ ft. is more than 14 ft.; it was thus left a margin of 10 ft. velocity, corresponding to a head of more than $1\frac{1}{4}$ ft., which had a tendency to overflow the pump-barrel. This would account for the amount of water equal to the full displacement of the piston, as the head necessary to overcome friction was found to be less than this difference. There appears to have been the following cause to account for the excess of water delivered: The total length of pipes was 70 ft.; they had to be filled with a solid column of water, there being no air-vessels on the pump, and there could be no air in the water except that drawn in through the Kingston valve in the bilge, 20 ft. below the surface. The mean velocity of water in pipes was, at 100 strokes, more than 3 ft. per second. When the piston had its maximum velocity it was pushing this column of water, and, reaching the end of the stroke and hesitating an instant before the commencement of the return stroke, this column of water could not be instantly stopped without bursting the pipes, but must have continued its motion until its momentum was exhausted. The velocity of 3 ft. per second would carry it up about $1\frac{1}{2}$ in. in the stand-pipe if the piston should hesitate long enough. The total travel of the water might be $18\frac{3}{4}+1\frac{1}{2}$ in., and the per cent. of piston displacement delivered, $\dfrac{18\frac{3}{4}+1\frac{1}{2}}{18\frac{3}{4}}=1.08.$

The maximum excess at this speed would be 8 per cent., which would be reduced by the resistance of the passages. There could be no gain of efficiency from this cause; for, although a portion of the water had gone through the pump without effort, when the piston commenced its return stroke it would press on the water at rest, or nearly so, which must be set in motion at the expense of the steam. The results computed from the indicator cards taken from the forward pump were as follows:

Data from Indicator Cards of Circulating Pumps.

DETAILS.	First Experiment.	Second Experiment.	Third Experiment.
Number of strokes	63.46	79.64	95.8
Steam, mean pressure	8.6	9.72	10.62
Steam, back pressure	2.77	6.24	9.84
Steam, total pressure	11.37	15.96	19.96
Water, mean pressure	7.118	7.678	8.88
Pressure necessary to work pump, steam-pressure less water-pressure (mean, 1.77)	1.482	2.049	1.78
Actual horse-power (one pump)	6.5	11.2	14.7
Actual horse-power at reduced head (one pump)	2.46	4.86	7.1

DIMENSIONS OF STEAM-PUMPS.—The following table gives the

Principal Dimensions of Several Varieties of Steam-Pumps.

DETAILS.	NAME OF PUMP.				
	Eclipse.	Clayton's.	Cameron's.	Knowles.	Blake's.
Diameter of steam-cylinder, in	12½	12	12	12	12
" of water-cylinder, in	7	7	7	7	7
Stroke, in	18	9	18	12	12
Diameter of steam-pipe, in	2	2	1½	2	1½
" of exhaust-pipe, in	3	2½	2	2½	2½
" of suction-pipe, in	5	4	4	5	4
" of delivery-pipe, in	4	3½	3	5	3½
Area of suction-valves, sq. in. each end	20	14	14	25	30
" of delivery-valves, sq. in. each end	20	14	14	25	30
Displacement of pump-plunger in one stroke, cub in	692.7	346.3	500	461.7	461.7
Capacity of air chamber on suction-pipe, cub. in.	1,400	346.5	1,000	600	600
" " " on delivery-pipe, cub. in.	4,000	698	1,500	1,000	1,000
Diameter of fly-wheel, in	52	36	....	....	....
Weight of fly-wheel, lbs	1,000	350	....	....	....
Length of pump over all	9 ft. 5 in.	5 ft. 6 in.	5 ft. 6 in.	5 ft. 7 in.	5 ft. 1 in.
Width of " "	3 ft	2 ft. 3 in.	2 ft.	1 ft. 7½ in.	1 ft. 6 in.
Height of " "	5 ft. 8 in.	4 ft	4 ft. 3 in.	3 ft. 9 in.	3 ft. 10 in.
Total weight, lbs	5,500	1,300	1,775	1,395	1,300

COMPOUND STEAM-PUMPS.—Early in the history of steam-pumps, the attention of makers was directed toward economy of steam. With a direct-acting steam-pump, steam cannot be expanded in one cylinder, the pump presenting the same resistance at all points of the stroke, so that the final force on the steam-piston should not be any less than the initial. The remedy was found in the adaptation of a compound engine, and for this particular use the arrangement gives an indisputable advantage. In a compound steam-pump, the steam, after the completion of a stroke, instead of exhausting into the atmosphere or a condenser, enters a second cylinder, much larger, where it expands before it is condensed. The two cylinders are generally placed in line, one in front of the other, with their pistons attached to the same rod.

In a direct-acting compound steam-pump, the range of expansion is generally somewhat limited. This can be best illustrated by tracing the action during a stroke. The effective pressure per square inch on small piston equals the total pressure per square inch on this piston diminished by pressure per square inch on large piston, or back pressure on small piston. Hence, if the effective area of large piston be found by subtracting the area of small piston, the back pressure on small piston need no longer be taken into account. Suppose, now, that the relative areas of the two pistons are as 1 to 6, and consider the force acting on the small piston as unity. At the commencement of the stroke, the pressure per square inch is about the same on each piston, and the effective area of the large piston being 5, the total force acting is 6 + vacuum. At the end of the stroke, the steam in the large cylinder has expanded to about one-sixth of the initial pressure, so that the total force is 1⅚ + vacuum—a variation in initial and final forces that is too great to be allowable in practice. In the practical working of the pump, however, there are some modifying conditions, which tend to decrease this difference. Steam, after completing its work in the small cylinder, finds considerable space, in pipes and the steam-chest, where it expands; it enters a cold cylinder which has been subjected to the action of a condenser, and thus some of it is condensed. The vacuum at the beginning of the stroke is seldom as perfect as at the end. All these circumstances tend to equalize the initial and final forces. It will be observed that, as the difference is less between the sizes of the two cylinders, the starting and the final forces are more uniform; and in reality compound steam-pumps never attain such high expansion as is common in the case of crank and fly-wheel pumping engines.

Mr. Worthington, in the arrangement of his duplex pumping engine, has accomplished the desirable end of obtaining almost a perfect uniformity of the propelling force by the use of a cross-exhaust. Two compound engines, working side by side in such manner that when one commences its stroke the other is in its second half, admitted the possibility of imparting the excess of force of one engine to the deficiency of the other, by conducting pipes from the exhaust of the small cylinder of one engine to the large cylinder of the other. A self-adjusting valve controls the flow of steam.

Messrs. Cope & Maxwell apply to the valve arrangement of their compound pumping engines the

self-governing feature described on page 620, the effect being that steam, instead of being admitted to the small cylinder throughout the stroke, is withheld till needed, and then admitted only as required. A single valve is used for each cylinder. In its operation, it places one end of large cylinder in communication with condenser; places both ends of small cylinder in free communication; places one end of large cylinder continuously in communication with one end of small cylinder, maintaining in the former a constant pressure, just sufficient for the work. Such action by the valve is coincident with the commencement of the stroke. No expansion, of course, takes place in the small cylinder, as the steam is simply shifted; but as the steam is being gradually but constantly admitted to the large cylinder, the pressure will soon reach a point too low for the work; at this point the valve closes connection between the ends of the small cylinder, and, opening free communication between the steam end of the large cylinder and the opposite end of the small cylinder, admits live steam to that end of the small cylinder.

Direct-acting compound steam-pumps with intermediate reservoirs, on the plan of expansion attributed to Ernest Wolff, a German engineer, with modifications patented by Mr. Worthington, have been built by the latter in some special cases. In this arrangement the large and small cylinders are placed side by side, forming a duplex compound engine with but two cylinders. Steam from the small cylinder exhausts into a reservoir or tank, which is of considerable capacity, thus allowing the steam to expand within. From this reservoir the large cylinder takes its supply of steam. The relative capacity of the reservoir, being large, does not admit of any considerable variation in steam-pressure by the contribution of the small cylinder to its contents, or by the withdrawal of steam from it by the large cylinder.

Walker's Compound Steam-Pump.—Fig. 3560 represents Walker's patent compound steam-pump, manufactured by E. & A. Betts, Wilmington, Del. Only the engine is shown, the pump-plunger being attached, as in all direct-acting pumps, to the piston-rod. The peculiar feature of this compound pump is that it has but one cylinder. The elongated piston has two ends provided with packing, and has a cylindrical portion of a lesser diameter extending between these ends, the said portion being fitted to work steam-tight in a central partition in the cylinder; two annular chambers are thus formed, into which steam is admitted to act upon the smaller areas of the piston-ends, and it is afterward expanded into the spaces between the piston-ends and the cylinder-covers, to act upon the larger areas of the piston; a cylindrical valve regulates the movements of the steam, each end of it being formed with a passage to connect two ports, through which steam passes from the annular space to the space between the piston and the cylinder-head, and also with a passage which connects the larger steam-space with the exhaust-passage. Steam is admitted into a space in the centre of this valve, and finds its way by minute openings into the end spaces between the valve-ends and valve-box covers; these end spaces are connected by very small passages with ports formed in the aforenamed partition, and as the piston moves to and fro, passages formed in the piston establish a communication between the said ports and a port leading into the exhaust-passage, thus relieving the valve from pressure on one end and causing it to be quickly pushed in that direction by the steam at the opposite end. The ports are all so arranged as to provide effectually for sufficient steam to cushion both the piston and valve, so as to prevent striking under any circumstances. A handle is used for moving the valve in warming the cylinder, which is stationary when the pump is running.

3560.

The following are the principal dimensions of one size of these pumps: Diameter of steam-cylinder, 12 in.; diameter of the trunk of the piston, 10¼ in.; area of low-pressure piston, 113 sq. in.; area of high-pressure piston, 26½ sq. in.; ratio, 4½ to 1; diameter of steam-pipe, 2 in.; of exhaust-pipe, 2½ in.; of suction- and delivery-pipes, 4 in. each; area of suction- and discharge-valves, 13 sq. in. each; diameter of water-cylinder, 7 in.; stroke, 14 in.; displacement of plunger, 538 cub. in.; capacity of air-chambers: for discharge, 1,614 cub. in.; for suction, 1,076 cub. in.; length over all, 7 ft. 8 in.; width, 1 ft. 9 in.; height, 4 ft. 4 in. The pump can be run from one-third of a stroke to 300 single strokes in a minute. R. H. B.*

PUNCHING AND SHEARING MACHINERY. The usual effect of perforating iron plates by punching is a weakening of the metal about the holes, so that the tensile strength per unit of section between the holes is less than that of the unpierced plate. According to experiments by Mr. Kirkaldy made in 1875, Yorkshire iron loses from 13 to 17 per cent. of its tensile strength, and Krupp iron from 10 to 13 per cent., by punching. For experiments on punching iron, see *Proceed-*

* Prepared by T. F. Krajewski, under the direction of R. H. Buel.

ings of the Institution of Civil Engineers, xxx., 169-70. As to punching steel, see experiments of J. G. Smith, *ibid.*, xlii., 76; also Kirk's experiments in *Proceedings of the Institute of Naval Architects*, Glasgow, 1878.

In a paper read before the Institute of Naval Architects in April, 1878, Mr. B. Martell, Chief Surveyor of Lloyd's Register, gives the following results of experiments showing the comparative advantages of punching and drilling steel:

"1. That very thin steel plates suffer less from punching than iron plates.

"2. That the difference in loss of strength in punching in steel and in punching in iron does not appear sufficiently great to require special precautions in the use of steel up to eight-sixteenths of an inch in thickness.

"3. That in plates above eight-sixteenths of an inch in thickness the loss of strength in iron plates by punching ranged from 20 to 23 per cent., while in steel plates of the same thickness it ranged from 22 to 33 per cent.

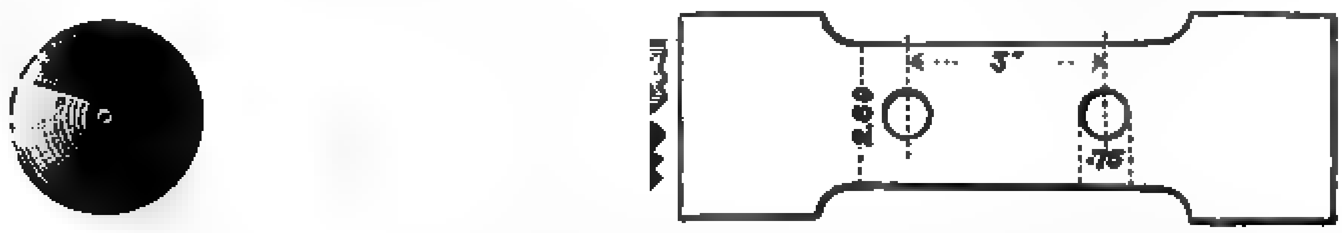
"4. That by annealing, after punching, the whole of the lost strength was restored, and in some instances greater relative strength was obtained than existed in them before.

"5. That in punching the steel was injured for only a small distance around the holes; and that by reaming with a drill larger than the punch previously used from one-sixteenth to one-eighth of an inch around them, the injured part was removed and no loss of strength was then observed.

"6. That in drilled plates no appreciable loss of tensile strength could be discovered."

The Spiral Punch, invented by Mr. D. Kennedy of New York, has proved an important advance in the direction of rendering annealing or reaming after punching unnecessary. The construction of this tool is represented in Fig. 3561. The principle on which it is based is exceedingly simple, namely, that it does its cutting at an angle, and bears the same relation to the flat punch that a shears with inclined blades does to a similar tool having its blades parallel and straight, a corresponding advantage being secured in economy of power. According to Mr. Martell, in the paper

3561.



above referred to, "in seven experiments made with two holes punched in each specimen, as shown in Fig. 3561, one with the flat punch and the other with the spiral punch, all the specimens broke through the hole made by the flat punch." It is also stated that a ¾-inch spiral punch penetrated a ⅝-inch plate at a pressure of 22 to 25 tons; while a ¾-inch flat punch, to pierce the same plate, required from 33 to 35 tons. The strength of material after using the spiral punch was determined to be about 2¼ tons per square inch greater than after the ordinary method of perforation, while greater ductility existed about the holes.

Pressures required for Punching.

Table showing Pressures and Sizes of Punch for Sheets of Copper, Brass, and Iron.

Diameter of Punch.	Pressures. Brass, .05 Inch Thick.	Pressures. Copper, .16 Inch thick.	Pressures. Iron, .105 Inch thick.	Diameter of Punch.	Pressures. Brass, .05 Inch Thick.	Pressures. Copper, .16 Inch thick.	Pressures. Iron, .105 Inch thick.
Inches.	Lbs.	Lbs.	Lbs.	Inches.	Lbs.	Lbs.	Lbs.
1.5	8,475	15,998	23,978	.7	3,772	7,327	11,468
1.375	7,728	14,570	21,445	.6	3,267	6,700	9,772
1.25	6,980	13,275	19,689	.5	2,635	5,107	7,916
1.0	6,450	11,078	16,595	.4	2,158	4,055	6,600
.9	5,692	9,788	14,178	.3	1,678	3,435	4,970
.8	4,889	8,580	12,692	.2	1,110	2,240	3,353

Table showing Punching Pressures in Iron, Copper, and Brass, for Circular Hole 1 Inch in Diameter.

Copper, Pressure.	Brass, Pressure.	Copper and Brass, thickness of Sheet.	Iron, Pressure.	Iron, thickness of Sheet.	Copper, Pressure.	Brass, Pressure.	Copper and Brass, thickness of Sheet.	Iron, Pressure.	Iron, thickness of Sheet.
Lbs.	Lbs.	Inch.	Lbs.	Inch.	Lbs.	Lbs.	Inch.	Lbs.	Inch.
21,248	......	.3	92,671	.615	3,362	5,448	.045	40,486	.268
15,543	......	.206	76,968	.565	..	4,997	.044	35,712	.245
11,068	......	.150	69,984	.510	2,589	3,780	.034	27,978	.183
7,461	......	.100	62,591	.445	2,212	3,540	.032	22,218	.140
......	......	...	57,698	.404	......	2,964	.029	16,518	.104
3,646	......	.050	51,868	.358	1,544	2,449	.022	9,459	.057

The amounts given in the foregoing tables may vary somewhat according to the quality of the metals. A general rule for wrought iron is that about 50,000 lbs. pressure is required for punching a circular hole one inch in diameter through a plate one-third of an inch thick, and that this force varies in direct proportion to the area of the hole and the thickness of the metal. Thus, to punch a hole half an inch in diameter through iron one-sixth of an inch thick would require but one-eighth

the above pressure. The diameter of a punch for thick plates is commonly about three-sixteenths of an inch less than the die; for thinner plates, one-eighth or even one-sixteenth of an inch less. Upon the amount of this difference depends the degree of taper in the hole; for the side on which the punch enters will correspond to the size of the tool, while the lower portion of the piece forced out of the plate will correspond to the hole in the die, thus making a tapered orifice. This peculiarity may be rendered useful in riveting by giving the rivet when compressed into the hole the form of a double cone; and care should be taken to punch the hole from the inside, or the side next the plate to which it is to be riveted, that the taper in the hole may be in the direction favorable for the rivet.

COLD PUNCHING.—*The Flow of Solids.*—The flow of solid bodies under pressure has been experimentally investigated by M. Henri Tresca, President of the Société des Ingénieurs Civils. (See papers read by him before the Institution of Mechanical Engineers, 1867 and 1878.) He states that "for all bodies two distinct periods are recognized: the period of perfect elasticity, which corresponds to variations of length proportional to the pressures applied; and the period of imperfect elasticity, during which the changes of dimensions, on the contrary, increase more rapidly than the pressures. If the second phase of deformation be alone considered, it is easily understood that it leads finally toward a condition in which a given force, sufficiently great, would continue to produce deformation, so to say, without limit—such as may be observed in the process of drawing lead wire. This particular condition, in which the deformation is indefinitely augmented under the operation of this great force, constitutes in fact the geometrical definition of a third period, which has been designated by the author as the period of fluidity, and to which the greater part of his experiments on the flow of solids are related. The period of fluidity is more extended for plastic substances; it is necessarily more restricted and may altogether disappear in the case of vitreous or brittle substances. But it is perfectly developed in the case of the clays and in that of the more malleable metals. In his paper of 1867, the author considered the deformations of these substances by flow under certain given conditions; such as the flow of a cylindrical block through a concentric orifice, or through a lateral orifice, one of the most novel subjects of his researches; also plate-rolling, forging, and punching. It was there demonstrated that in these different mechanical actions the pressure was gradually transmitted from place to place, with loss from one zone to another, in absolutely the same manner as in the flow of liquids, and with a regularity not less remarkable, but following a much more rapid law of diminution. The pressure may be very considerable at certain points, while it may be nothing at all at other points; and the study of the various modes in which pressures may be transmitted constitutes in fact a new branch of investigation, to which M. de Saint-Venant has given the name of plastico-dynamics. It is chiefly in the operation of punching metals that this mode of transmission of pressure has been manifested, while the processes of forging, on their part, have afforded the means of establishing the correlation between those molecular phenomena and the development of heat which is their direct consequence."

Cold-Punched Nuts.—A series of experiments has been made by Mr. David Townsend (*Journal of the Franklin Institute*, March, 1878) in order to investigate the flow of metal during cold punching; the object being to prove that an actual flow does take place under pressure, which flow is governed by some law not yet enunciated. Among other tests was that of partially punching bars of the same thickness with punches that had the same diameter, but which varied in length according to the depth of the hole to be punched. The bars were uniformly $1\frac{1}{1}\frac{3}{8}$ inch thick, and the punch $\frac{7}{16}$ inch in diameter. The flowing of the metal in downward curves is here plainly visible in sections of the bars when planed and etched with acids. The layers in this case are all severed, and the line of parting of the core from the block is apparent. This property of flowing in downward curves Mr. Townsend considers to be highly advantageous to the quality of nuts thus made, as "on being tapped the thread is made up of several layers instead of one, and the strain which comes on them is taken on end instead of across the grain, thus giving the iron a much greater resisting power. The process of punching these thick bars does not depend for its successful performance upon the time taken, but upon the accuracy and power of the machine and the quality of the punch. The element of time is introduced only so far as the wear and tear of the tools and the machinery determine it; as for the flow, that remains the same whether the motion is fast or slow."

The manufacture of cold-punched nuts has been largely carried on by Messrs. Hoopes & Townsend of Philadelphia, who have perfected a process of manufacture whereby the holes are punched at right angles to the top and bottom of the nut, and, while there is a slight concave and convex surface, the bearing is even, and there are no imperfections or fins to be removed after the nut leaves the machine. The relative strength, etc., of nuts thus made and of hot-pressed nuts (see FORGING MACHINES), has been investigated by Prof. R. H. Thurston, and the results of his tests are embodied in a report to the manufacturers dated August 21, 1877. The object was to determine the resistance to stripping and to bursting of several sets of hot-pressed and of cold-punched nuts of four sizes, viz., $\frac{1}{2}$ inch, $\frac{5}{8}$ inch, $\frac{3}{4}$ inch, and $\frac{7}{8}$ inch. Very full tables of data were compiled, showing that the cold-punched nuts are from 25 to 40 per cent. stronger than the hot-pressed nuts in stripping and bursting stress, and justifying the conclusions: "1. That the cold-punched nuts possessed a much greater average strength, combined with greater rigidity and slightly greater uniformity, than were exhibited by the hot-pressed nuts; and that the superiority was most strongly manifested in the trials by stripping stress. 2 That the cold-punched nuts exhibited a strength never attained by the hot-pressed nuts, but that such variations in the strength of both styles occurred as to have caused the hot-pressed nuts to equal and occasionally to excel in strength the weakest specimens of cold-punched nuts." In the matter of the comparative cost of finishing 1,000 cold-punched and 1,000 hot-pressed nuts, Prof. Thurston reports that the number of grindings of tool in facing the bottoms was as 9 to 59, in chamfering the tops as 7 to 56, and in planing the sides as 17 to 174, in favor of the cold-punched nuts. Details of other experiments on cold-punched nuts will be found in the *Railroad Gazette*, Nov. 3, 1876.

Punching Machines.—For blacksmiths' punches, see Forging. Fig. 3562 represents Kennedy's hand-punch, which embodies a powerful knee-joint mechanism. The construction will readily be understood from the engraving. With spiral punches, it is claimed that this machine is capable of punching $\frac{3}{16}$-inch holes in iron an eighth of an inch thick.

Hand-punches exist in a very large variety of forms. They are often constructed so as to be operated by hydraulic pressure. (See Bear, Punching.) Punching presses are employed for cutting out blanks for buttons (see Button-making), for pens (see Pens), and other small articles in sheet metal. Their commonest form is the screw-press, in which a long weighted lever rotates a vertical screw of quick pitch, which acts upon the end of the punch. A circular flange on the end of the screw is engaged by a collar-box on the upper end of the punch so as to retract the same in the backward movement. The punch has a square shank which moves in the guide-socket.

Fig. 3563 represents an improved form of power-punching press made by the Stiles & Parker Press Company. It is important that a press of this kind should be so arranged that it may be stopped after a single revolution and at the top of its stroke, in order that the work may not be spoiled by the return of the die before the workman brings it into the right position for the succeeding action of the punch, and in order that there may be the greatest possible amount of room for the adjustment of the piece. Many ways of accomplishing this result have been tried. The exceedingly

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ingenious method adopted in the press represented in Fig. 3563 is shown in Fig. 3564. The upper end of the pitman A, carrying the slide F, is bored out and enlarged to receive an eccentric disk B. The lower end of the pitman is secured to the slide by the pin G. The disk B is bored out of centre and fits the crank-shaft loosely. The disk is turned by the pinion g, and is held by the screws D. By this device the stroke is not changed, but the punch is raised or lowered to the direction in which the disk is turned; or in other words, the limits of the throw are altered by the full range of the eccentric. When it is turned down, the punch rises clear of the metal to be perforated, then descends through it and into the die. When turned up, the punch still rises and falls, but never descends so far as to strike the plate or piece of metal which the workman is adjusting upon the die.

Heavy punching machines are used for making the holes for rivets in boilers, tanks, flues, and other structures made of thick wrought-iron or steel plates. Their construction is necessarily strong and massive, and, as great power is to be exerted at short intervals, a heavy fly-wheel is often provided to maintain a uniform movement of the parts and thus obviate sudden strains.

Punching machines are very commonly combined with shearing machines, the work of both being essentially the same. In some cases the construction is such as to allow of the removal of the shear-blades and substitution of the punch, and *vice versa*, as desired. More usually, however, the two contrivances are separate, though arranged in the same supporting frame. Fig. 3565 represents a

punching and shearing machine manufactured by Messrs. W. Sellers & Co. This is a lever machine, or in other words one in which the vertical slide which carries the punch is operated by a lever, the long end of the latter being actuated by a lifting cam. In another class of punching machine the pressure of the cut comes on a crank-pin. It is stated that in comparing machines using crank and lever, if in both cases the same gearing between pulley and work, making the same number of strokes of the same length per minute, be used, there is a capability of punching larger holes with the use of a lever than of a crank. In the Sellers machine a box is provided at the back of the frame, to hold a block of wood to receive the fall of the tail end of the lever on its quick return motion; the regulation of the height of this block adjusts the length of stroke of the punch, thus enabling it to be set close to the sheet or bar being punched. The shear is intended for cutting plate iron of usual thickness for boilers; it will shear $\frac{5}{8}$-inch plate. The punching side has its dies so arranged in a holder as to permit the punching of flanges of boiler-heads which are as small as 12-in. in diameter, the punching being done from the outside or marked side of the head, and flanges turned out on the end of flues can be punched vertically. The holes in the dies for use in these machines are made larger than the punches by the following formula, expressing the diameter and thickness in sixteenths of an inch: The diameter of

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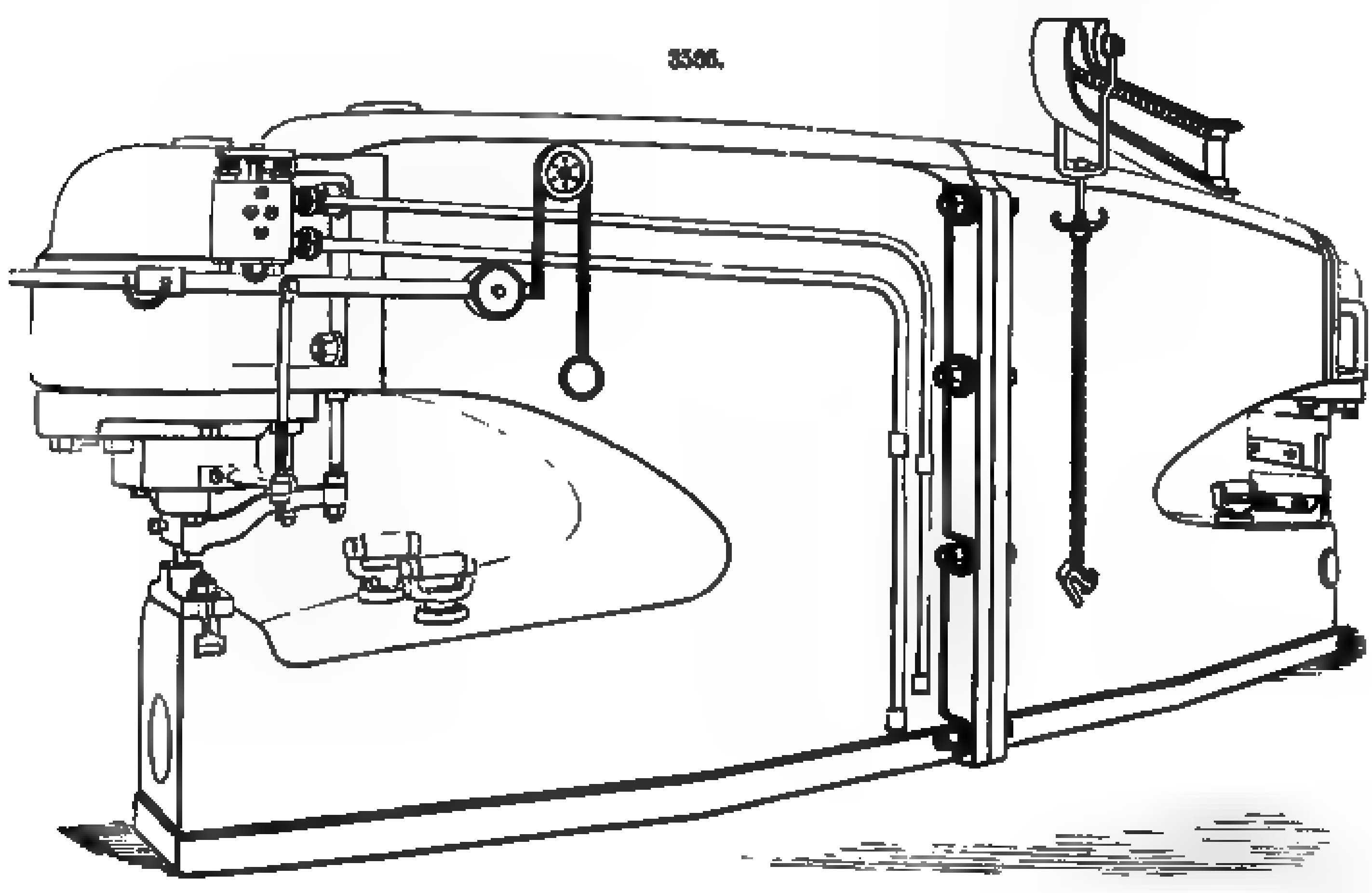

the die-hole = diameter of punch, plus $\frac{2}{10}$ the thickness of the plate ($D = d + 0.2\,t$). Thus, for iron plate $\frac{6}{16}$ of an inch thick, the diameter of the punch being $\frac{7}{8}$ of an inch, the diameter of the die-hole will be 15.2 sixteenths of an inch—say $\frac{15}{16}$ inch. This method of making the die-hole larger produces a taper hole in the plate, but allows the punching to be done with less consumption of power, and, it is said, with less strain on the plate.

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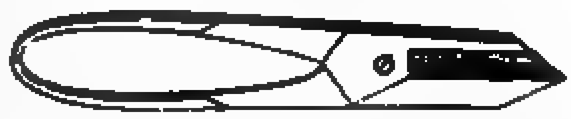

Tweddell's Hydraulic Punching and Shearing Machine is represented in Fig. 3566. The movable shear and punch are attached to plungers operated by hydraulic pressure. The whole machine weighs about 28 tons. It will punch $1\frac{1}{2}$-inch holes in $1\frac{1}{4}$-inch plate at a distance of 5 feet from the edge; and it shears $1\frac{1}{4}$-inch plates 5 feet from the edge, taking at each cut a length of 18 inches. This long cut is a great advantage in straight work, and reduces the number of strokes to cut the same length of plate fully one-third as compared with the ordinary geared machines; the knives also can be turned round, so as to cut at right angles to the centre line of the machine, at an angle of 45° either way, or in a line with the centre line, thus enabling bars of any length to be cut to the length required. The drawback motion is self-acting; and by means of tapped rods and nuts, as shown on the punching end in the engraving, the length of stroke, and consequently the consumption of water, can be regulated so as to be proportionate to the thickness of plate punched or sheared. The levers admitting the pressure and opening to exhaust can either be worked by the man in front of the plate being operated upon, or from behind by the chain as shown. It may be added that no stop motion is required in these machines, as the machine becomes stationary at any point of stroke the moment the man working it releases the handle.

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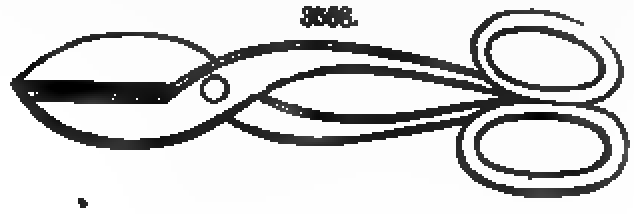

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SHEARING MACHINES.

Power required for Shearing Machines.—According to Dr. Hartig's experiments, the power necessary to drive shearing machines when empty is expressed by the formula, $P = 0.1 + \frac{n \times t^2}{26.7}$, in which P = horse-power, t = maximum thickness of plate to be cut, and n = the number of cuts per minute. In the following formula, a = the area of surface cut or punched per hour in square inches, and $F = (1166 + 1691\,t)$, a factor expressing the work required to produce a cut or sheared surface of 1 square inch. The power required to do the work itself, in addition to that required to drive the tool when empty, is $P = \frac{a\,F}{33{,}000 \times 60} = \frac{a\,F}{1{,}980{,}000}$. For example, a shearing machine cutting 4,643 square inches of surface per hour, in plates 0.4 inch thick, would absorb 0.68 horse-power empty and 4.3 horse-power in effective work; total, say 5 horse-power.

Hand-Shears.—The simplest forms of hand-shears are represented in Figs. 3567 and 3568, which are known as snips, and are used by sheet-metal workers in cutting out work. Bench-shears, such as are used by the same class of mechanics, have blades measuring about one-fifth of the total length, which is usually from $1\frac{1}{2}$ to 4 feet. One of the handles is turned downward close to the pivot, and terminates in a square tang inserted in the bench or in a heavy wooden block. The other handle constitutes the lever whereby the blades are worked, and is sometimes forged thicker at the end to increase the cutting effect by its momentum when suddenly depressed.

There are about as many forms of hand-shears operated by means of mechanical contrivances as there are of hand-punches. Fig. 3569 represents a powerful machine of this class constructed by MM. Dandoy-Maillard, Lucq & Co., of Maubeuge, France. The arrangement of the double articu-

lated lever is well calculated greatly to augment the power This apparatus will cut plate iron .2 inch thick and round bars .5 inch in diameter. The cutting blades are about 8 inches long.

Fig. 3570 represents Kennedy's shears, constructed in substantially similar manner to the hand-punch by the same maker already described. The largest size of this device cuts $\frac{3}{4}$-inch by 4-inch bar iron and $\frac{1}{2}$-inch round rod. The weight is 140 lbs.

Fig. 3571 represents a shearing machine made by MM. Dandoy-Maillard, Lucq & Co., which is operated by hand or power as desired, and from which the shearing blades may be removed and punches substituted. The largest size of this apparatus punches holes .9 inch in diameter through, or shears plates .62 inch thick. Its weight is 4,046 lbs.

Power Shears.—Sellers' Plate-Shearing Machine is represented in Fig. 3572. *A* is the upper shear attached to a slide which moves vertically in ways in the frame, and is operated by a pitman or lever which is pivoted to the frame at *G*. The lower end of this lever extends down between the side-framing, where motion is communicated to it in the following manner: Upon the lower end of the lever is a rack segment engaging with a spiral pinion, similar to that used in the Sellers planing machine. (See PLANING MACHINES, METAL.) This pinion is driven by the shaft to which the gear-wheel *B* is attached. The direction of revolution of the spiral pinion is reversed by reversing the motion of *B*, which is accomplished by means of a gear, the construction of which is also shown in the reversing mechanism of the planing machine. The plate to be sheared is clamped to the frame by screws, and through the placing of the upper shear at an angle may be cut to any extent. The reversing or stop motion may be so set that any given number of plates may be divided to a fixed distance. The upward movement of the shear is effected by means of the pivoted links *D*. For shearing curved plates, curved shears are substituted.

Circular Shearing Machine.—Fig. 3573 represents a shearing machine manufactured by M. Leblanc of Paris, in which the cutting apparatus consists of two circular blades rotated by the gearing

shown. This class of machine is especially suited for cutting metal in curved form. The apparatus represented is capable of dividing plates 7 inch thick.

PYROMETER. An instrument for determining degrees of heat higher than those which can be measured by ordinary thermometers. Pyrometers are required in the determination of the intensity of the heat of furnaces, and in ascertaining at what temperatures metals melt and chemical compounds are formed or decomposed. They may be arranged, according to the principles on which they act, in the following classes: 1. Pyrometers using the expansion of solids as a means of measuring high temperatures, of which class Daniell's is a type; 2. Those using the contraction of baked clay, as Wedgwood's; 3. Those employing expansion of air, as Pouillet's, Regnault's, and Jolly's; 4. Those using the known melting-points of solids; 5. Those depending on the chemical decomposition of solids, as Lamy's; 6. Those measuring temperatures by heating a known weight of water, and allowing to cool in it a known weight of platinum or other metal, which has been heated to the temperature of the space or of the body to be tested, as Pouillet's; 7. Those which determine temperatures from the measures of the strength of thermo-electric currents produced by heating the junction of two different metals, as Becquerel's; 8. Those which determine temperatures by the measurement of changes produced by heat in the electrical resistance of a length of platinum wire, as Siemens's; 9. Those which use the expansion of the wave-length of a sound, which traverses a tube placed in the furnace whose temperature is to be measured, as Mayer's.

A full theoretical discussion of the principal forms of these instruments, by Prof. A. M. Mayer, will be found in the "American Cyclopædia." For further information see an article entitled *Pyrometrische Versuche*, by A. Weinhold, in Poggendorff's *Annalen*, xxix., 1873. In this the author gives the bibliography of the subject, and details of his experiments with all pyrometers to decide their relative values in practice.

QUARRYING MACHINE. For quarrying stone or excavating in rock, the machine illustrated in Fig. 3574 is employed. The engine is carried on a wrought-iron four-wheeled frame, running upon rails laid down over the site upon which the machine is to work. On each end of the main shaft is a fly-wheel *A*, carrying a crank-pin to which is attached the connecting-rod *B*, which with *F* is coupled to the frame by the pin *C*. The upper end of the lever *B* passes through a sliding plate attached to the crank-pin, and a reciprocating motion is imparted to the lever *B* by the revolution of the fly-wheel. The corresponding end of the lever *F* passes through a guide *G* bolted to the bottom of the vertical frame shown in the drawing. Motion is communicated from the upper to the lower lever by means of coupling-bars, between which rubber blocks *D E* are placed. The end of the lever *F*, passing through the guide *G*, gives motion to the group of five cutting tools *I H*. These bars are of steel, placed side by side, and move in top and bottom clamps, as shown. The two bars *I* have chisel-ends set diagonally, while the others are square. The middle bar *H* is wider than the others, and extends to a somewhat lower level. By this arrangement, when the machine is advancing, the front pair and the middle chisel operate, and in traveling in opposite direction the rear cutters come into action. Within the top clamp there is a series of serrations, in which corresponding serrations in the chisel-bars fit, so as to prevent any movement.

Upon the main shaft is a worm *J*, which drives the worm-wheel *K*, the shaft of which extends diagonally toward the back of the engine and terminates in a bevel-wheel. On the rear axle are two other bevel-wheels, which can be moved to and fro by means of the lever *M*, so that either can be thrown into gear with the bevel-wheel first mentioned, and the machine is moved to and fro by this mechanism. Motion to the cutters is given by means of the lever *F*, which drives them up and down, the upper clamps serving as guides in the fixed standards.

The machines are made to cut channels at three different distances apart—4 ft. 6 in., 6 ft. 3

in., and 6 ft. 7 in. The standards can be set to any angle between a vertical position and one of 45°. The number of blows struck per minute is 150 on each side, and the rate of advance is 6 ft., the depth of cut varying from one-half inch to 1 inch, according to the nature of the material; and channels can be cut to a depth of 6 ft., but a depth of 13 ft. in sandstone has been cut.

QUARTZ MILLS. See MILLS, GOLD AND SILVER, and STAMPS, ORE.

RABBLE. See IRON-MAKING PROCESSES—PUDDLING.

RACK AND PINION. See GEARING.

RADIATOR. See HEATING BY STEAM AND HOT WATER.

RAG-DUSTER. See PAPER, MANUFACTURE OF.

RAG-ENGINE. See PAPER, MANUFACTURE OF.

RAILROAD, OR RAILWAY. A road with wooden, stone, or iron sleepers, supporting timber, iron, or steel ways, or rails, upon which the wheels of carriages may run. The graded earthen or stone embankment or cut which supports the road is called the road-bed, while the sleepers, rails, etc., constitute the superstructure.

For motive power on railroads, see articles under LOCOMOTIVES. For rolling stock, see RAILROAD CARS. See also BRIDGES, BRAKES, and SIGNALS. Exceptional classes of railroads are treated in succeeding articles under appropriate heads.

The question of location of railroads is a broad and difficult one, and cannot be discussed in the limited space of a cyclopædia. It involves moreover questions not purely of an engineering character. In the appended works of reference the literature of the subject will be found.

Resistances.—The following are the chief causes of resistance to motion on roads: 1. Want of uniformity in the surface of the road, the weight of the load having to be lifted over projecting points and out of hollows or ruts, thus diminishing the effective load which the power may draw to such as it can lift. 2. Want of strength of the road-bed, let its surface be as even or uniform as it may, adds another impediment to the movement of a load over it, with the additional disadvantage that, while the power is endeavoring to lift the load from a cavity or hollow, the fulcrum, which in the first case was supposed to be rigid and fixed, is in the latter yielding and variable, subjecting the power to the constant effort of lifting instead of simply drawing. 3. The grade of the road, or the quantity by which it differs from a level. This resistance is due to the force of gravity, and, unlike the others, may be determined from the well-known laws of mechanics, while the former are determinable entirely by experiment on the road in question or a similar one. 4. The curvature of the road. This resistance is caused by the construction of carriages which are designed to run to the best advantage on a straight road. Any divergence from the latter occasions extra resistance. There are also resistances to motion on roads which are independent of the imperfections of the road, such as the friction of the axles and resistance of the air.

The first cause of resistance above noted is in large measure overcome in the railroad by substituting for the uneven gravel or pavement a hard and smooth iron surface, or the rail. The second cause of resistance is diminished by a system of constructions, the aim of which is to afford the iron rail a permanent and unyielding support.

The whole art of railroad building, then, consists in producing, for the carriage to roll on, a hard, smooth surface, upon an unyielding foundation or road-bed

To exhibit at a glance the value of a smooth surface: From experiments made upon the best turnpike road in England, and probably in the world, the following was found to be the force of traction, or the weight in pounds which, hanging over a pulley, would draw one ton on a level part of the road, the road-bed being as firm as most railways: On a well-made smooth pavement, 33 lbs.; on a broken stone surface (macadamized) over an old flint road, 65; on a gravel road, 147; on a macadamized road, on a rough permanent foundation, 46; on a macadamized surface, on a foundation of cement and gravel, 46; average, 67 lbs On a good edge railroad, the force of traction on a level is usually taken for one ton at 8 lbs.; or a horse will draw from 5 to 18 times as much on a good railroad as upon the best turnpike roads in use, and this is due to the smoothness of the surface alone.

For the second cause of resistance, it may be stated that a locomotive engine built at Lowell drew, on trial, on the Lowell and Boston Railroad, up a grade rising 30 feet per mile, the same load which it barely drew on a level part of the inferior railroad upon which it was subsequently worked. The surfaces in the two cases were the same, wrought iron; but the one road-bed and rail was firm, and the other yielding.

The engine which could draw, say, 300 tons gross on a grade rising 30 feet per mile, the rail perfectly firm, would, in the same condition of rail, draw 475 tons on a level. This illustrates the value of a firm and unyielding road surface.

The third and fourth causes, as also all other causes of resistance to motion on railroads, are treated in the articles on LOCOMOTIVES.

CONSTRUCTION OF RAILROADS.

Excavation and Embankment.—Let $A\ B\ C$, Fig. 3575, represent a profile or longitudinal section of a portion of the line over which the railroad is to pass, and $a\ b\ c\ d$ the level at which the road is to be formed, constituting what is called the *grade line*. All those parts of the section above the line $a\ b\ c\ d$ will require to be cut down, and are called *cuttings;* and those portions below this line will require to be filled up, and are designated as embankment, or *fillings*.

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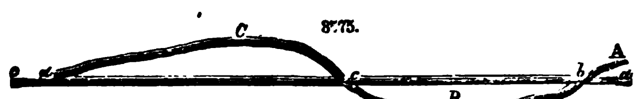

Road-bed, or *formation level* as it is sometimes called, is the top of the embankment or the bottom

of the excavation; it receives the ballast and the permanent way,* which latter consists of cross-ties or sleepers, chairs, rails, fish-plates, frogs, crossings, switches, and fastenings. The width of the road-bed depends upon the gauge of the track (the distance between the inside edges of the heads of the rails of one track or line), the number of tracks, the distance between the centres of tracks if there

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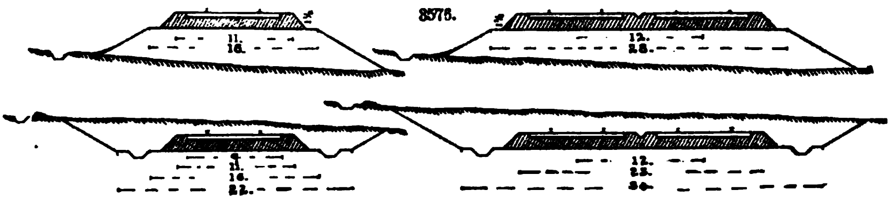

are more than one, the length of sleepers, the slopes of the ballast, and the width of side ditches if these are used. Fig. 3576 shows the cross-sections of the average American single- or double-track roads in fillings and cuttings. The shaded portions represent the ballast, and the dotted lines are the levels of the road-beds.

The dimensions of the standard French and English roads, for a gauge of 4 ft. 8½ in., are given in the following table, in comparison with the American:

EXCAVATION AND EMBANKMENT.	WIDTH OF ROAD-BED.				
	French Standard.	English Standard.	AMERICAN.		
			Average.	Least.	Greatest.
	Ft.	Ft.	Ft.	Ft.	Ft.
Excavation, single track	30	31	22	18	25
" double "	42	43	34	31	40
Embankment, single track	20	21	16	18	28
" double "	32	33	28	25	30

Gauge.—The standard railway gauge in most countries of the world is 4 ft. 8½ in. Gauge wider than this is called *broad gauge*, and if narrower, *narrow gauge*. In 1832 a horse tramway, known as the Festiniog Railway, was built in Wales for the purpose of carrying slate from the quarries of Port Madoc. It was nominally of 2 ft. gauge, and was used as originally designed until 1863, when Mr. C. E. Spooner, the engineer of the line, recommended the use of locomotives. In 1869 Mr. Fairlie designed a locomotive known as the "Little Wonder," which weighed 19½ tons, and which achieved notable results on the Festiniog road This, and the writings of Mr. Fairlie in 1870 and 1871 on "The Gauge for the Railways of the Future," attracted the attention of engineers throughout the world to the question of the gauges.

The advocates of narrow gauge or Fairlie's system claim: 1, that the cost of constructing, taking the average expense, will be found to vary as the gauge; 2, that every inch added to the width of the gauge beyond what is absolutely necessary for the traffic adds to the cost of construction and increases the dead weight of the rolling stock and the cost of working; 3, that the dead weight of the trains is in direct proportion to the gauge on which they run; 4, that a saving in first construction, equal in many cases to 33 per cent., can be made by the adoption of the narrow gauge, which allows greater curvature, narrower banks, and lighter bridging, rails, and ties; 5, that narrow-gauge railroads have relatively greater traffic capacity than roads of the standard gauge; and finally, that they are safer and can be more economically maintained and operated.

The controversy on the gauge question has reached no definite conclusion. The arguments relating to it will be found fully discussed in the files of the *Railroad Gazette*, *Engineering*, and *Engineer* from 1870. The weight of opinion of all eminent American engineers, however, is in favor of the standard gauge.

The following statement gives the different gauges used on railroad lines in every part of the world: United States, 3 ft., 3 ft. 6 in., 4 ft. 8½ in., 4 ft. 9 in., 4 ft. 9¼ in., 4 ft. 9½ in., 5 ft., 5 ft. 6 in., 6 ft.; Great Britain, 4 ft. 8½ in., 7 ft.; Ireland, 5 ft. 3 in.; British India, 3 ft. 3⅜ in., 5 ft. 6 in.; Canada, 3 ft. 6 in., 4 ft. 8½ in., 5 ft. 6 in.; Nova Scotia, 4 ft. 8½ in., 5 ft. 6 in.; Australia: New South Wales, 4 ft. 8½ in., Victoria and South Australia, 5 ft. 3 in., Queensland, 3 ft. 6 in.; Tasmania, 3 ft. 6 in.; New Zealand, 5 ft. 3 in.; Cape Colony, 3 ft. 6 in.; Ceylon, 5 ft. 6 in.; Egypt, 3 ft. 6 in., 4 ft. 8½ in.; Brazil, 3 ft. 3⅜ in., 3 ft. 6 in., 4 ft., 4 ft 3 in., 4 ft. 8½ in., 5 ft. 3 in., 5 ft. 6 in.; Argentine Republic, 3 ft. 3⅜ in., 5 ft. 6 in.; Chili, 5 ft. 6 in.; Japan, 3 ft. 6 in.; Russia, 5 ft.; Spain and Portugal, 5 ft. 6 in.; France, Germany, Holland, Belgium, Austria, Hungary, Turkey, Switzerland, Italy, Sweden, Norway, Denmark, Peru, and Uruguay Republic, 4 ft. 8½ in. Some of the above enumerated European countries possess also narrow-gauge railroads, which are, however, only of very small local importance.

The width or space between tracks depends on the width of the rolling stock. American passenger cars are from about 9 to 10 ft. wide on the outside, and the space between the cars should not be less than 2 ft.; thus the space between the tracks would be about 12 ft., less the gauge.

Slopes of Excavations and Embankments.—The angle to be given to the slopes of the excavations and embankments depends in some degree upon the depth of the excavation or height of the embank-

* The name "permanent way" is employed in distinction to a temporary track used during construction of the road.

ment. In the former, when the material is sand, gravel, or gravelly clay, a slope of 1½ horizontal to 1 perpendicular is quite sufficient; and in excavations, up to 30 or 40 ft., this slope has been found to stand very well. In some descriptions of clay a greater slope is given, sometimes as much as 2 to 1. The embankments are generally made with the same slope as that of the excavations; and it is presumed that, with whatever slope the excavation will stand, the embankment formed of the material from such excavation will stand with the same angle of slope.

On the English railways the slopes are covered with a layer of soil, which is procured from the base of the embankments or from the top of the cuttings; this layer of soil is spread over the face of the slope about 6 in. thick, or of the thickness which the soil from those places will yield. It is of great importance to the security of the slopes that the soil should be laid on as soon as possible after the excavation is made, or the embankment consolidated, and sown with grass or clover, or both, to get a turf upon it before the slopes are affected by the action of the weather. By doing so slopes will often stand where, without the soiling and turf, exposed to the action of the weather, they will not stand. In some cases, where stone is plentiful, and where there is an excess of cutting, side walls, similar to Fig. 3577, are built, to retain the sides of the excavation, $p\,q$ showing in that case the line of the slope. In such cases, stone drains, similar to that shown at g, are made to still further diminish the width of the railway. The propriety of doing this is entirely a matter of calculation.

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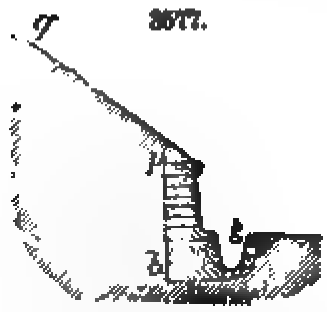
3577.



Ballast.—The road-bed, having been formed to the proposed inclination longitudinally, is leveled transversely, and is then ballasted. The ballast forms the foundation for the ties upon which the rails rest, and its object is to effect drainage. It is obvious that if water were allowed to accumulate between and under the ties, or in the ballast generally, the pressure of passing trains would set the water in motion, working the ballast into mud, which would soon allow the ties to settle. Ballast should therefore be composed of a hard, unfriable material, which will not crush under the weight of trains, and which will admit of efficient drainage. Usually gravel, broken stone or bricks, burnt clay, slag from blast-furnaces, or similar substances are used for the purpose. In Fig. 3578 is shown the rounding of the upper surface of the ballast, high in the centre and gradually sloped toward the sides. A space is left under the rails to afford escape for the water. This is especially important if the natural soil is used for ballast, as is often the case in this country. The depth of ballast should not be less than a foot to provide against heaving of the track from frost, and a still greater depth is preferable. If stone ballast is used, it should be broken into pieces not exceeding 2½ in. in any dimension, and all coarser stones should be separated and placed at the bottom. The width of the ballast at its upper surface should be such as to allow it to project about a foot and a half beyond the ends of the cross-ties, to prevent them from moving laterally.

Culverts.—Railroads often cross depressions in the soil which are the natural water-drains. In such places culverts, which are small openings or tunnels, are placed below the upper structure of the road, allowing the water to pass beneath. They are built either of stones or bricks, or partly of wood.

Ties or Sleepers.—To distribute the weight supported by the rails over a larger surface of the ballast, and to attach the latter firmly, sleepers or ties are laid on the ballast. They are usually made of wood, but lately also of iron in localities where wood is more expensive. Stone sleepers were largely used in England in the early days of railroad construction. They consisted of stone blocks, about 2 ft. square and 1 ft. thick, placed about 3 ft. apart between centres. Cast-iron chairs supporting the rails were attached to them by means of wooden treenails driven into holes made in the stone. This method presented some serious disadvantages. The stone being non-elastic, it was difficult to attach the chairs firmly to it, and traveling on the road was exceedingly rough and unpleasant. Rails laid in chairs attached firmly to a solid rock were also tried, but without success, for the same reasons.

Wooden sleepers are most generally used. These are placed across the track—hence the name of cross-ties; but sometimes they are placed longitudinally, or in a combination of both these systems. It is important to have the cross-ties of uniform length, width, and breadth. Ordinarily they are of rectangular shape, and rarely half rounded, the flat portion being then placed at the bottom, and the top adzed at the centre to secure a flat space on which the chair or the rail is seated. Ties of triangular shape with a horizontal side up were used when locomotives were of much lighter construction than at present. Hard wood is always necessary, to prevent the rail from sinking into it. In this country, cross-ties on the standard-gauge roads are usually 8 in. wide and 7 in. deep; they are about 4 ft. longer than the gauge, and are spaced not more than 2 ft. apart from centre to centre, and about 16 in. at joints, if suspended joints are employed. Longitudinal ties, which are rarely used, give a continuous support to the rail, which may therefore be much lighter. The Great Western Railway of England has a 62-lb. rail in combination with longitudinal sleepers, while on cross-ties it uses a rail of 75 to 80 lbs. for the same traffic. Longitudinal sleepers are connected at intervals by transoms,

slightly notched into them and secured to them by bolts, the object of which is to maintain a correct gauge. The disadvantages that this system presents lie principally in the greater cost of laying such sleepers on the road, and still more in maintaining them in order. Wooden ties fail from rotting in the ground, or from the cutting of the chairs of the rail into them. Chemical treatment (such as creosoting, kyanizing, or application of sulphate of copper) is often resorted to, to preserve them from rotting under the action of the moisture and also from attacks of insects.

Iron sleepers have long been used in England. Pot or bowl sleepers, represented in Fig. 3579, are dome-shaped, about 23 in. in diameter at the bottom and 5½ in. high. The ballast is laid beneath

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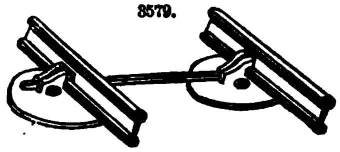
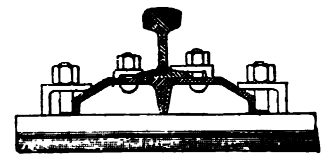


3580.



them in heaps to fill their interior, and through holes in their upper surface small ballast is rammed in to pack them close. Cross tie-rods are used to maintain the gauge. Rolled iron sleepers are made either as cross or longitudinal sleepers. Numerous systems of these were exhibited in Paris in 1878 (for a complete statement see *Revue Général des Chemins de Fer*, October, 1878, and January, 1879), some made of new iron, some of old rails rolled into a new form, some of combinations of wood and iron, etc. As an example, Fig. 3580 illustrates Hilf's system, of which some 600 miles have been laid in Germany. It consists of a steel rail attached firmly to a longitudinal sleeper of rolled iron, the cross-section of which is shown in the cut, by means of 44 angles and bolts. The rail is 9 metres long, less the play for expansion, and the longitudinal sleeper is somewhat shorter. The rails are jointed by means of the ordinary fish-plates and bolts, and the longitudinal sleepers are attached at each joint (which comes directly under the rail-joint) to a cross-sleeper, which is also rolled, and is of the same shape as the longitudinal one. Longitudinal slipping of the rail is prevented by one of the rail-fastening angle-plates abutting against the fish plate. Another form is a rail which dispenses entirely with the use of sleepers, which from its shape was called "saddle-back." This was placed directly on the ballast, which filled the cavity beneath its wings. Practice has shown that it is not well suited for high speeds or heavy traffic. Toughened glass (see Glass, Manufacture of) has been used for sleepers and chairs with promising results. (See *Engineering*, xxviii., 270.)

Rails, Chairs, Rail-Joints, and Rail-Fastenings.—Rails made of cast iron were used at first, but they were soon discarded and replaced by rolled rails. There are two typical forms of rails now used most generally: the *double-headed rail* shown in Figs. 3581 and 3582, which is in use in England and

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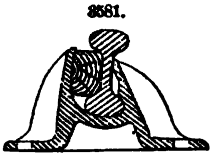
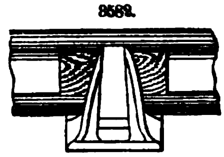


3582.



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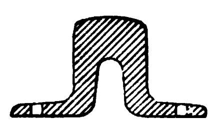

France, and the *flat-bottomed rail*, known as the American pattern, and often called "Vignoles" from the name of an eminent European engineer who has largely used it, and which is shown in Figs. 3584 to 3587. There is a third pattern called *bridge-rail*, introduced by Mr. Brunel in England, which is still used on the Great Western and some other broad-gauge railroads, on longitudinal sleepers. Its section is shown in Fig. 3583. The first pattern has been considered as possessing great advantages over the others, the metal being well disposed for vertical strength, and the manufacture being easier. The rail being reversible, an economical advantage is thus obtained. We shall see how far these advantages are real. Rails are laid on the ties, to which they are fastened. To keep a double-headed rail in a vertical position, it must be supported at the sides. The heads not being sufficiently wide to afford the required bearing on the tie and prevent the sinking of the rail into the wood, some method of increasing the bearing is necessary. These two requirements made it necessary to use "chairs," as they are called, in combination with the double-headed rail, thus increasing the cost. The general form of a cast-iron chair is shown in section and side elevation in Figs. 3581 and 3582. A wooden wedge is driven between the rail and one arm of the chair, to keep it in position. Such chairs were formerly made to weigh about 20 lbs.; but as it was found that the lower head became injured by the great pressure, and more so by the constant hammering of the rail on the chair if the wedge admitted of any vertical play, the size of the chair was constantly increased, until now chairs weighing 50 lbs. are used. To avoid this defect, a bracket-chair is employed on some roads. This consists of two distinct pieces of cast iron, shaped to fit under the upper head of the rail, and which, extending below the bottom of the lower head, holds it suspended. A bolt passing through both brackets and the web of the rail holds all firmly together. This chair, resembling an angular fish-plate, is considerably lighter, but it can be attached only at that point of the rail where the hole is made to receive the bolt. It is generally found in practice that the rails after being reversed wear out rapidly.

The flat-bottomed rail, with its wide base, has sufficient bearing to be laid directly on the ties without chairs. Spikes are driven on each side of the rail into every cross-tie, holding the rails firm laterally, and preventing them from rising vertically. In regard to the last-mentioned consideration,

ordinary spikes are not as efficient as is desirable, as they are generally partly forced out by the passage of a train. Wood-screws and other devices have been tried for the same purpose, but they have shown special defects which have prevented their use. On some roads in Europe flat-bottomed rails are fastened to the ties by means of bolts called "fang-bolts," which either pass through holes made in the foot of the rail, or hold its foot by means of a clip. The bolts pass through the cross-ties, and are fastened underneath by nuts bearing against fangs, which latter are washers usually of a triangular shape, with corners turned so as to cut into the sleepers.

In fastening the rails to the ties great care must be taken to keep a uniform gauge and to leave the necessary space between the rails at the joints for expansion. The gauge is always wider than the distance between the flanges of wheels, the difference usually being from five-eighths to three-quarters of an inch. This gives the freedom to the rolling stock, and especially to the locomotives, to oscillate in the horizontal plane without forced knocking of the flanges on the rails, which is destructive to both. On curves the gauge is made still wider, and the amount of play allowed here is in proportion to the length of the rigid wheel-bases of the rolling stock; otherwise a car or locomotive could not change its position from the tangential. Track-layers are usually provided with an instrument called a "gauge," one form of which, known as "Huntington's gauge," is shown in Fig. 3578. This instrument has one of its heads forked to give a sufficiently wide base to bear against one rail, and to take a perpendicular position to the rails, measuring thus the true distance between them. The space between the ends of two rails, which allows a free expansion, should be, with the present length of rails, which is 30 feet, three-eighths of an inch in winter, in cold climates, and one-sixteenth of an inch in summer. It is the custom on many European railroads to place the rails in an inclined position, to suit the inclination of the cone of the wheels (the treads of wheels on rolling stock being portions of cones and not of cylinders). The chairs of double-headed rails are arranged to give this inclination, and for flat-footed rails the cross-ties are adzed. An observation of the wear of new rails, which commences on the side of the head inside of the track, proves the correctness of this method.

The surplus elevation of the outer rail on curves, the object of which is to counteract the centrifugal force of the train in motion by the force of gravitation, although it can be calculated exactly, yet, on account of the different speeds of trains causing a varying centrifugal force, cannot be made to suit all cases. Generally it is calculated by the formula, $e = gv^2 \frac{1}{1.25r}$, in which e is the super-elevation of the outer rail in inches, g gauge in feet, v speed in miles per hour, and r the radius of the curve in feet. "The Road-Master's Assistant," by William S. Huntington and Charles Latimer (New York, 1878), contains tables giving the super-elevations calculated for various curves, gauges, and speeds.

In the beginning of railway construction it was not thought necessary to connect the rails rigidly endwise, but the ends were laid in an extra-large chair. It was, however, discovered that the ends were injured from the blows received by the wheels of passing trains, which first depress the end of one rail and then mount on the other—it being impossible in a chair to keep them on the same level. Rail-joints were then introduced (about 1847), and are now used universally. They are either suspended joints if the ends of the rails come between the cross-ties, or supported joints if the ends of the rails are placed on the tie. The latter should always be used if the joining parts are not as strong as the rail itself. Fish-plates were the first joints introduced, of which Fig. 3584 represents the ordinary form. The two splices or fish-bars, as they are called, are long enough to give room for four bolts, and project a short distance beyond the outside bolts. The upper and lower edges of the bars are made to conform to the inclines formed by the bottom surface of the head and the upper surface of the base, by which arrangement they can be drawn tightly and form a rigid support to the head. The holes in the web of the rail are either oval or of a larger diameter than that of the bolts, to relieve the bolts from the strain caused by expansion of the rails. To prevent turning of the bolts, holes in the bar which receives the heads of bolts are often made oval, and that portion of the bolt under the head is made to conform to the shape of the hole. Sometimes this bar is provided with a groove throughout its whole length, in which the heads of the bolts fit and are thus prevented from turning. (For lock-nuts, see Nuts and Bolts.) Double-headed rails are also jointed in the same manner.

To make the joint stronger, instead of the ordinary fish-plates, angle-bars are used. Fig. 3585 represents a cross-section of such a joint as used on the New York, Lake Erie, and Western Railroad. Such joints are suspended, the distance between the cross-ties being only about 10 in. They are strong vertically and laterally, and give a wide foot-base. The outside bottom edges of the bars are notched to receive spikes.

The Atlantic and Great Western Railroad uses a double joint, consisting of fish-plates and a chair. Fig. 3586 represents its cross-section. The chair is made in two parts, which are held together in the centre by one bolt, passing underneath, hooking at one end, and provided with a clip under the nut. Two wooden washers, one for each two bolts, about an inch thick, are placed under the iron washers of the nuts of the fish-plate bolts; the elasticity of wood prevents the nuts from getting loose.

The Baltimore and Ohio Railroad uses a joint which consists of a wooden splice 3½ in. high, 4½ in. wide, and 5 ft. long, which is bolted to the outside of the rail. Only a light fish-bar is bolted on the inside (with two bolts for a 64-lb. rail, and four bolts for a 72-lb. rail), and an iron plate 6 in. wide is placed under the joint.

A joint known as the Fisher joint dispenses with the fish-bars, and supports the rails only at their base. Its cross-section is represented in Fig. 3587. It consists of a flanged bar placed under the foot of the rails and between the cross-ties. This bar is rigidly connected with the rails by means of three U-shaped bolts, each with two nuts. Between the foot of the rail and the nuts are placed two

iron bars, one on each side of the rail, which provide a long bearing for the nuts, and give additional strength to the joint.

There are many other designs for rail-joints used by different railroads in this country, which are either combinations of the above or slightly differ from them.

The great variety of the forms of rails and their joints, their frequent failures, and the differences of opinion regarding this subject, all show that the question of rails is a difficult one, and that an ultimate settlement of it has not been reached.

The American Society of Civil Engineers has rendered a valuable service in appointing a committee of able engineers, who after diligent study and careful examination have given reports on the form,

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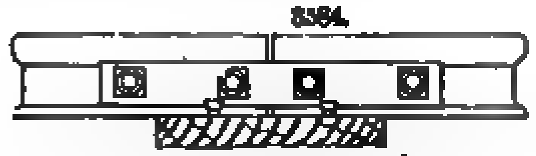

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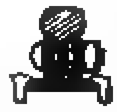

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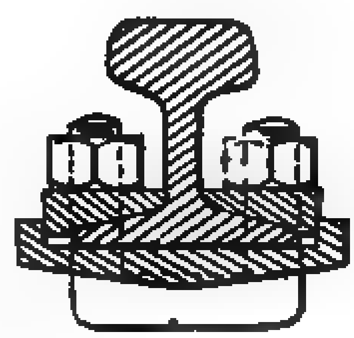


endurance, and manufacture of rails. (See *Transactions*, or *Railroad Gazette*, vol. vi., 1874, pp. 269 and 288, and vol. vii., 1875, p. 474.) The following are extracts from their reports:

A rail has two principal functions to perform: as a beam or girder, to carry the weights between *actual* supports without overreaching the limit of elasticity, and to distribute the weight bearing on one point of the rail among the adjacent supports, for which requirements strength and stiffness are necessary; as a wearing surface, to resist crushing and endure the wear, for which hardness, breadth, and area of section to wear off are required. A rail is divided into two parts: one that wears off, or the consumable; the other that remains, or the residuary. The endurance depends on the first; the strength and stiffness should depend only on the latter.

The principal modes in which rails become unfit for service are: breaking, crumbling, laminating, splitting, splintering, scaling, mashing, wearing down the top, wearing off the running side of the head, breaking off the projecting part of the head when worn down thin, and hammering down and otherwise disfiguring the ends. The principal proximate causes of these injuries in this country are: brittle, crumbly, lamellar, splintering, scaly, soft (unequal at the same level), imperfectly welded, weak, or permanently strained metal; insufficient wearing surface of the head in proportion to the weight on it and the hardness and elasticity of the metal; unevenness from mashing or wearing down soft spots, so making shocks; uneven or inelastic foundation; ties too far apart or rotten; extreme cold, supposed to render the metal more brittle, and rendering the road-bed uneven and inelastic; bad joints; very flat wheels; and accidental collisions or blows. The principal remote causes are: metal from bad stock, such as cold-short, red-short, cinder, etc.; insufficiently worked, burnt, imperfectly welded, too much or too little carbonized, too high- or too low-tempered, permanently strained in cooling, of unequal hardness or otherwise badly manufactured, punching, head too small, stem and base so heavy as to make the rail too rigid, under side of head too steep or narrow, or curving to hold the fish-plate; fish-plate too short, narrow, soft, or weak; uneven surface or alignment of track; road-bed uneven, clayey, or wet; ballast too shallow or too coarse, or of unequal depth; stone ballast on clay without intervening stratum of sand or gravel, or very fine broken stone; unequal settling of embankment or earth under the ballast; ties rotten, too far apart, too thin, short, soft, or badly bedded; base too narrow for the surface and hardness of the ties; steep grades, sharp curves, high speeds, heavy weights, bad springs; wheels small, or with inelastic faces; sliding of the wheels; wheels worn into grooved faces; dirt on track; numerous stops and starts; changes of climate; and of course heavy traffic, and the enormous amount of unnecessary dead weight of cars continually dragged back and forth. Some of these proximate causes act by the abrasion of sliding wheels, as on steep grades, on curves, or from conicity of the wheels. Too great weight crushes the metal. Traction causes the minute grain, fibres, or particles of the top of the rail to be alternately

pulled one way by the drivers, then the other way by other wheels, till finally they are loosened and rubbed off.

The best form of rail-section should be considered in regard to the different conditions under which it is used. Most metal is required where there is the most wear, on the head; the other parts should be as light as experience safely dictates. The head should be broad on the top to give as much wearing surface as possible. Examination of rail-surfaces nearly 3 in. wide shows that they are evenly worn all over, forming a plane surface slightly inclined toward the running side. Whatever may be the contour of the face of the wheel at first, it wears into such form as to bear all across a wide rail. The area of contact being greater on a broad tread, the pressure per square inch is smaller, and consequently the endurance increased. The breadth of the head and the depth necessary for strength being ascertained by the ordinary calculation for beams, and by experience under actual or similar circumstances, the additional depth to give consumable metals should depend on the amount of traffic. Supposing the rails to be steel or iron that will only give way by wearing out, let R represent the cost per mile of the residuary part of the rail, C the cost of the metal the traffic is expected to consume in each year, L the loss, including inconvenience and incidental expenses, on each renewal, besides the cost of the metal to replace that consumed, T the intervals between renewals, and a the rate of accumulated interest for that time. Then $C\,T$ will be the consumable part of the rail, and $R + C\,T + \dfrac{L + C\,T}{a} = V$, value of a rail that will last for ever, or the present value of the cost of the rails and their renewals for ever, traffic being constant. Of course T, which determines the consumable depth of head, should be such as to make the above value V the smallest possible. (See paper on the "Comparative Economy of Steel and Iron Rails," by Ashbel Walsh, C. E., in *Transactions of the American Institute of Civil Engineers.*) Suppose the residuary part of a mile of steel rails cost \$7,000, and its renewal \$4,000; then, if $C = \$50$ per annum, T should be about 30 years, so that $C\,T = 1{,}500$; if $C = 100$, T should be about 20, so that $C\,T = 1{,}800$; if $C = 200$, T should be about 16; if $C = 400$, T should be about 14; if $C = 600$, T should be about 12; if $C = 800$, T should be about 10; and if $C = 1{,}000$, T should be about 8, so that in this extreme case the consumable part of the head should cost \$8,000, or more than all the rest together, and the head would be 2¼ or 2⅜ in. deep.

The top corners of the head should not be much rounded, for that diminishes both the width of the top and side wearing surfaces; and even if rounded at first, it becomes nearly angular on the outside by use. The top of the head should have a convexity of about 12 in. radius. The under side of the head should be as broad as possible, to have the greatest bearing on the top of the fish-plate. The outer corners of the under side of the head should not therefore be rounded, but sharp. This gives also greater wearing surface to the side of the head. The inclination of the top of the base and bottom of the head, where in contact with the fish-plate, should be about 4 horizontal to 1 vertical, or about 14° from horizontal. As to thickness of stem, half an inch for iron and seven-sixteenths of an inch for steel is sufficient. The base should be broad so as not to cut into the cross-ties. For good white-oak ties, 4 in., covering full 30 per cent. of the ground under the rail, is sufficient, but not so for ties of soft wood unless it is very elastic, like cypress. Soft-wood ties require 40 per cent. of the ground under the rail, or the base should be 4½ in. or more. For the edge of the base three-sixteenths of an inch is sufficient. The base should be thin. Metal for strength should be put into the head rather than into the base. Experience seems to have sanctioned a height of about 4½ in. for rails of 60 lbs. weight per yard, over 4 in. for those between 50 and 60 lbs., and 3½ in. for those under 50 lbs. Bolt-holes should be drilled, not punched, through the stem. The base should not be notched at all, but the rail held from traveling longitudinally by straps connecting fish-bolts and ties. The fish-plates should be of steel, and long enough. The English practice of using chairs does not allow long fish-plates, which are thus only 14 in.; but American should be, and often are, twice as long.

The committee proposes several patterns of rails, formed according to the foregoing principles. Fig. 3585 represents one of these patterns as designed and adopted by Mr. O. Chanute, Chief Engineer of the Erie Railway. No definite relation between the proper weight of a rail and the weight of a wheel rolling over it can be given. The proper relation of the consumable part of the rail is not with the weight on a wheel, but with the amount and mode of the traffic. The relations of breadth of base are with weight on rail and amount and hardness of timber under it.

The really important inquiry is, what is the relation between the size and elasticity of and the weight on a wheel, and the width, hardness, and elasticity of the top of the rail? Experiments made by Mr. Chanute (see *Railroad Gazette*, viii., 171) show that a newly-turned driving-wheel, 5 ft. in diameter, bears upon a rail-surface only about one-fourth of a square inch. If, therefore, the weight on such a wheel is 10,000 lbs., the static pressure on the rail-surface in contact with it is about 40,000 lbs. per square inch; the dynamic pressure is still more. If the metal is so soft as to crush under this weight, as most wrought iron does, the top of the rail must not only be disintegrated so as to be easily wiped off by abrasion, but it must be expanded and elongated; a permanent longitudinal strain must take place, tending to tear apart the lower part of the head and all below it; and if it is not soon worn out, ultimate breakage must ensue. Increase in weight at best only postpones this breakage for a short time. Many rail-tops are actually elongated one-fourth inch. A wheel smaller in diameter will cause greater pressure per square inch than that of a larger diameter. As the crushing and consequent expansion of the metal extends but a short distance below the surface, all additional metal to counteract the strain should be put into the head.

For testing rails the drop and the dead weight have often been used too exclusively. They test the rail only as a beam, and the metal only as to brittleness and strength. The number of blows on any kind and pattern of rail very closely measures the lifetime of that rail as compared with others

of the same kind. It fully discloses the defects of the rail, as brittleness, softness, bad welding, lamination, etc. This, however, does not give the relative endurance of iron and steel, as it probably would if each was destroyed only by honest wear. Steel lasts many times as long as iron, not only because harder, stronger, more elastic and homogeneous, not coming to pieces, but perhaps mainly because as yet the weight on its surface is not great enough to crush it; whereas the weight on the same surface of iron, being too great for the material, crushes and destroys the fibre.

The endurance of rails is so dependent on various circumstances, that no definite average numerical value can be given. Some early rails are known to have been in use 25 or 30 years, while new and larger rails laid in the same track during part of the same time have given way within two or three years. The means of increasing the endurance, besides increasing the sectional area of the consumable part of the rail, are better metal, good ballast, moderate speeds, and moderate weights.

The breakage of rails, besides being due to such well-known causes as ties placed too far apart or unevenly laid, want of good ballast, bad joints, etc., is also caused by the elongation of the top of the rail by too great weight on a wheel in proportion to the bearing surface and the hardness of the metal. Rails break especially in winter, because the material is proved to be more brittle in very cold weather, the road-bed heaves irregularly and becomes inelastic, and the top of the head being elongated produces permanent longitudinal strain, which coöperates with the other causes. Insufficient allowance for contraction by cold may cause a longitudinal tension acting against the fish-bolts. From a report on this subject by Mr. Chanute, it appears that on a Western railroad there had been no breakage for 10 years after the rails were laid, then 200 or 300 in one winter, and then over 5,000 the next winter, showing that by use the rails became more breakable.

Regarding the comparative value of steel and iron rails, it seems probable that the best iron, if homogeneous and the head of uniform hardness, so as to wear off evenly, like steel, would, with machinery of moderate weight, wear a third or even half as long as steel. But, owing to want of homogeneousness and uniformity, the iron scales, splinters, laminates, or somehow disintegrates or mashes in spots before it wears out. Iron rails of fair ordinary quality carry from 2,500,000 to 6,000,000 tons freight, or from 4,000,000 to 15,000,000 tons gross load, according to weights, grades, speeds, and other circumstances. A steel rail may last 5 or 10 times as long as a really good iron rail, 15 or 20 times as long as those that pass for good, 30 or 40 times as long as the common run, and 50 or even 100 times as long as many rails made ten years ago, or since imported from the cinder-heaps of Great Britain.

Rail Manufacture.—Iron rails are made by rolling together several iron bars, which are collectively called a pile. The bars are variously arranged, and are either of the same width as the pile or shorter; in the latter case they are arranged so as to break joints and sometimes to change the direction of the grain. The top bar, which is to form the head, and is called a "slab," should be of the best hard-hammered, and if possible elastic, iron; it should be also homogeneous. For a double-headed rail a similar slab is placed at the base of the pile. For a flat-footed rail the base should be of strong and slightly ductile metal. Between the top and bottom bars puddle-bars are placed. The pile is heated in a furnace to a welding heat, and hammered or rolled into a solid lump or bloom, and then heated again and rolled into the finished form. It is of the greatest importance that the welding be perfect. In cooling and straightening, care should be taken that no permanent strain shall be engendered. The following rules are taken from a report of the Committee on Rails of the American Society of Civil Engineers:

"Select the stock best adapted to each part, the hardest metal for the head, the strongest for the base. Use only gray metal, not white. Put no old rails into the head or base; puddle thoroughly, or the metal will not weld thoroughly. Cut off and throw out all ends of puddle-bars; make the top slab about 1¼ in. thick (thicker will not heat before the small bars burn); pile 8 in. square. The top slab should be four-rolled (thrice heated), the bottom thrice-rolled, and the stem twice-rolled. Each heating should be uniform and thorough without burning, or the welding will be imperfect."

The welding of iron rails may be thoroughly tested by shearing off a short piece from the end. Each individual lamina will curl up by itself and separate from the others if the welding is not perfect.

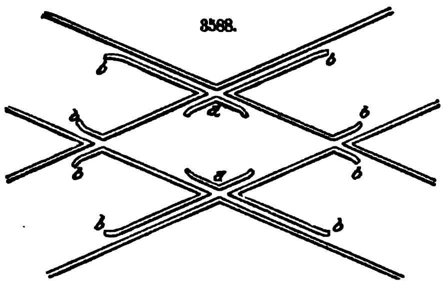
As the efficiency of welds depends on conditions not easily manageable by the skill of the workmen—as, for instance, on the absence of all cinders, and proper hammering at the proper heats—wrought iron, having also fibres and a grain like wood, and thus not being homogeneous, is not well adapted for transverse compressive strains and friction. The result is that iron has largely given place to steel as a material better adapted for the manufacture of rails. Since the Bessemer process has been applied in manufacturing steel rails, their price is not higher than that of iron rails of the best quality. Steel rails not only possess a higher tensile and compressive strain, but are homogeneous, the steel being cast into ingots from which they are rolled, being thus free from welds. It is also probable that the newly discovered processes of Messrs. Thomas & Gilchrist (see STEEL), for producing steel from phosphoric ores, will still further extend the use of steel rails.

Steel-topped rails are rails rolled from iron piles with a steel slab for the head. Their manufacture presents some difficulties. The steel and iron, welding at different heats, often do not unite, and a complete separation sometimes takes place. This difficulty is partly overcome by giving a channel form to the steel slab.

CROSSINGS.—If two tracks cross each other on the same level, the points of intersection between each two rails must be such as to admit the passage of the flanges of the wheels on either rail, without striking or mounting on the intersecting rail. An open space must thus be left; or, in other words, the rails cannot be continuous, but must be broken at the intersecting points. In the early days of railroads the rails were not broken on crossings, but one rail was elevated above the other, enabling wheels to pass over it, above the top of the lower rail. The elevated rail was pivoted so as to be moved out of the way for wheels rolling on the lower rail. Such crossings are still used

sometimes on temporary railroads; but they have been mainly replaced by a permanent or fixed crossing, with open spaces, or gaps, through which the flanges of wheels pass. Fig. 3588 represents such a fixed crossing. To prevent the wheels from entering a wrong gap, thus mounting the rails and leaving them, and to steady their lateral oscillations when approaching such points, guard-rails and wing-rails are introduced. Wing-rails, so called for the reason that they are wings or branches of the main rails, are indicated in the cut by the letter *b*; guard-rails, *a a*, are separate from the main line, and are always introduced inside of the parallelogram. The wing- and guard-rails are solidly connected with the nearest parallel rails by bolts, solid blocks of iron being introduced be-

3588.



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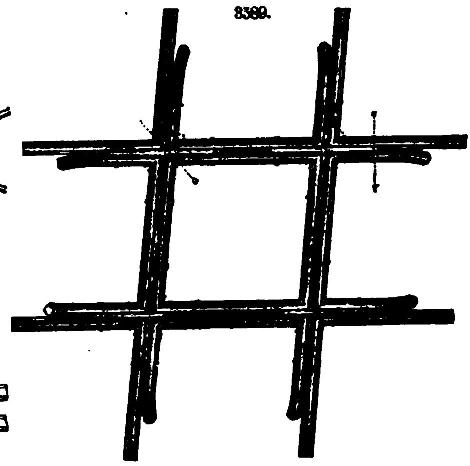

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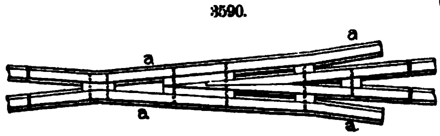

tween them. If the intersecting parallelogram approaches the form of a square, the guard-rails are usually extended so as to form a closed parallelogram. Square crossings are the most difficult to maintain.

Fig. 3589 represents a bolted steel-rail crossing made by the Pennsylvania Steel Company of Philadelphia. This is adapted to situations where the angle is near to a right angle (90°). The throat filling is made of wrought-iron bars crossed and fitted together at the exact angle, in such manner that it becomes a strong frame on which the rails are fitted and afterward secured by bolts. On the outside heavy braces are fitted into the angles and secured by the same bolts. This crossing has the advantage of allowing the replacement of any worn part with facility, and also of presenting but little obstacle to proper tamping and leveling of the track.

Frogs.—If from one line of rails there diverge one or more branch lines, to enable the rolling stock to be transferred from one of the lines to another without the use of turn-tables or traverses, switches are employed. In connection with switches frogs have to be used. A frog is the short portion of two intersecting rails which run to a point; it is thus a portion of a crossing when the angle of intersection is sharp. Frogs are made either of one solid piece of cast steel, or of rails rigidly connected together by means of iron blocks and bolts, or riveted to an iron plate forming its base. Fig. 3590 represents a steel-rail frog as commonly used. *a a* are the wing-rails which support the wheels entering on the point of a frog, thus preserving the latter from great wear or from breakage. On the other rail of the line, opposite the frog, a guard-rail is placed to steady the wheels laterally and prevent the flanges from striking on the frog-point. Frogs are difficult to maintain on account of the hard blows which they receive from wheels passing over them, notwithstanding the wing- and guard-rails. To diminish the intensity of the blows, an elastic base is sometimes laid under the frogs, which are then called *elastic frogs*. In the Mansfield frog, the base is composed of alternate layers of wood and iron. Rubber is also used sometimes for the bases.

A spring-frog, or as it is also called a *main-line frog*, gives a continuous bearing for one line; that is, its point comes close against one rail (that of the main line), leaving no intermediate channel. This is accomplished by means of a spring acting on a movable wing-rail, in such manner that the frog-point comes in contact with the rail of the main line. If a train of the branch line passes over such a frog in the direction toward which the frog is pointing, the flanges of the wheels force the wing-rail out, opening a channel which closes itself afterward by the elasticity of the

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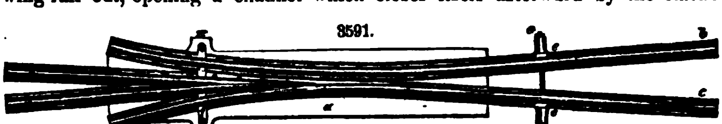

spring. If the train of the branch line passes over this frog in the opposite direction, the wing-rail is shoved by the action of the guard-rail, which guides the wheel on the opposite side of the line, keeping the wheels at gauge.

Fig. 3591 represents a spring-frog made by the Pennsylvania Steel Company of Philadelphia. *a*

is the plate; *b*, the fast rail; *c*, the spring-rail; *d*, the frog-point; *e*, housing for springs; and *f*, the cross-bar. The two pieces of rail which form the point are dovetailed together, and are secured by two or more heavy rivets through the web, besides the riveting through the bed-plate. The spring-rail (or movable wing-rail) lies close to the side of the point, and is retained there by strong springs. The standard length of this frog is 15 ft. for any required angle.

A cross-over track, shown in Fig. 3592, is a short diagonal line connecting two parallel tracks so as to enable trains to pass from one to the other, if desired, or isolating them at will; for which purpose at each end of the connecting track are placed switches.

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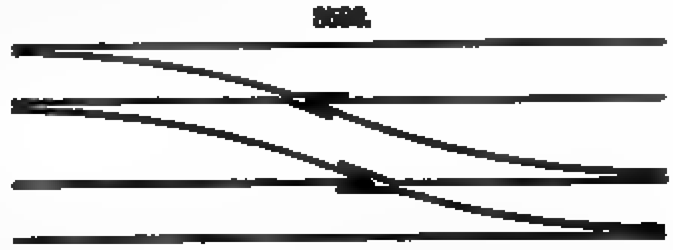

SWITCHES (for interlocking switches see SIGNALS) are movable rails, constituting essentially a portion of the track, by means of which a connection may be established between the main line and a branch or side track, and the continuity of the main line be broken; or the latter may be restored, breaking off the connection with the branch. There are two kinds of switches in use: the *stub-end switch*, which is generally employed in this country, and the *split-rail switch*, or *points*, which in Europe is used exclusively. The former is illustrated in Fig. 3593. If A A' represents the main line, B B' and C C' are two branches or sidings, diverging from the main line to the right and left. S S are two movable rails, of which the ends nearest to the branching rails are called *toes*, and those farthest from it are called *heels*. The heels are fixed points around which the toes move. Switch-rails are, however, not pivoted at their heels, but are connected to the adjacent rails by fish-bars, their considerable length permitting the small amount of motion required. Switch-rails are connected together by several tie-rods, *r r*. Their toes rest on a *head-chair* (a simple iron plate or casting), which also supports the ends of the fixed rails. The amount of motion of the toes each way is called the *throw* of the switch, and is usually 5 in.

3593.

B
A
C

B'
A'
C'

The switch is moved by means of a rod R connecting it with the lever L, which is pivoted on a stand D. In each position of the switch the lever is usually locked. The engraving represents the switch in position for the main line; if the connection should be made with one of the branches, the toes of the switch would be moved so as to place them in line with the respective branch. The switch represented is the so-called three-throw switch, as it joins three tracks. When it connects two tracks only, it is called simply a single switch. The principal objection to the stub-switches is that they cause a broken joint, as their toes cannot be rigidly connected like the other joints of the rails; and although the chairs provide partly for the strength of the ends, the open space which is left between these ends becomes gradually increased by the blows from passing wheels, which move the rails apart until the space allowed for expansion at the neighboring joints is all transferred to the switch-joints. This largely increases the wear of switches and the rolling stock, though this disadvantage can be much diminished by proper care. In *Dooley's stub-switch*, the toes of the movable rails are placed one a few feet back of the other, so that only one pair of wheels passes over each at a time.

The *split-* or *point-switch* is represented in Fig. 3594. A is a rail of the main line, and B of the branch, both continuous; A' and B' are the movable rails, called tongues or points, the ends of which are planed off to a point so as to fit up closely to the continuous rails, which are called stock-rails. To leave no projection against which the flanges may strike, the end of the point-rail is planed down so as to fit under the flange; or the stock-rail is notched or cranked to receive the end of the point. The tongues are connected to tie-rods and the switch-lever in the usual manner. The diagram represents the switch in position for the main line. Should it be shifted so as to bring the rail B' close to the rail A, the switch would be in position for the branch.

The three-throw split-switch is represented in Fig. 3595. In this only the two outside rails are continuous, while the others are points arranged in two pairs, each pair having one rail of the centre or main line. The arrangement shown in the diagram has the second pair of points placed immediately beyond the heel of the first pair of points, which is preferable. If the split-switches are placed on the track so that the trains run over them in the direction from the heels to the points, they are called "trailing points;" and if in the opposite way, they are called "facing points." The difference lies only in use, not in construction.

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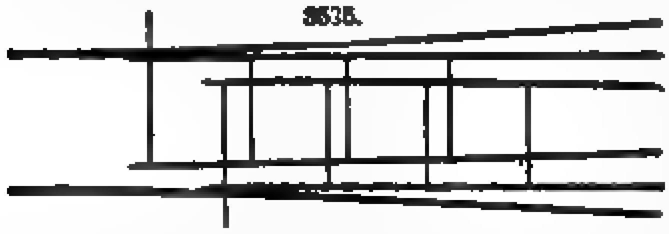

Safety-switches are so called from the fact that they prevent the train from leaving the track whether they are set right or wrong. Referring to Fig. 3594, it is clear that when the points are "trailing," and are set wrong for the approaching train, the flanges of the wheels will force their way between the point-rail and the stock-rail. To facilitate this action without injury to the connection with the switch-lever, counterweighted levers have been used in England. In this country this arrangement has been improved by the introduction of a rubber spring in the rods which operate the switch, in such manner that all strain coming on the rods is received by the spring *S*, Fig. 3594. This switch is widely known and used as the *Lorenz safety-switch*, from the name of its originator.

Some improvements on the foregoing switch will be found in *Ainsworth's safety-switch*, Fig. 3596, in which the two tongues are of different lengths, and the stock-rail *B'* of the longest tongue *A* is bent outward for a certain distance of its length. The whole amount of its lateral deflection is equal to the width of the head of the rail, thus allowing the projecting point of the tongue to be comparatively blunt, and to have its base but little diminished in breadth. The edge of the tongue *A* which is inside of the track coincides with that of the stock-rail (before it reaches the point); and as the heads of the two rails are also at the same height, the trains pass over the switch without jar or injury. Opposite the point of the projecting tongue is placed a guard-rail *C*, which prevents the flanges from striking on the projected point. Before the other wheel reaches the point of the shorter tongue *B*, the longest tongue acts as a guard-rail, in whatever position the switch may be, and thus protects the point of the tongue *B* against wheel-flanges. By means of a special mechanism connected with the spring acting on the rod *R*, the switch, if set for the siding while a train on the main line moving in the direction toward which the switch is pointing passes over it, sets itself right for the main line. The action of the spring is such that the connection with the switch-lever is rigid, until after the switch is "home" (fitting close to the rail). This arrangement prevents the throwing over of the lever in case snow or dirt is lodged between the point and the stock-rail, thus necessitating the removal of the obstructing material. (See *Journal of the Franklin Institute*, April, 1879.)

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The *single-tongue* or *Thiemeyer switch*, as its name indicates, is composed of but one movable tongue, while the other tongue is fixed. The movable tongue projects beyond the other, and according to its position acts as a guard-rail, forcing the wheels on the other side either to continue on the unbroken rail or on the fixed tongue.

The Wharton switch, which is one of the best forms in use, is represented in Fig. 3597. It leaves the main line continuous and unbroken. *A A'* are the continuous main-line rails, and *B B'* two

3597.

movable rails of the siding. *B* is a grooved rail with a point fitting to its stock-rail *A*, and *B'* is gradually elevated above the rail *A'* to a height sufficient to allow the wheel-flanges to clear the rail *A'*. The two switch-rails, which are tied with rods, are acted upon by the weighted lever *L*. The engraving represents the switch open, in which case trains moving in either direction on the main

line are entirely unaffected by the switch. Should the switch be thrown over for the siding, the grooved rail B guides the flange of one wheel for the siding, while at the same time the other wheel mounts on the elevated rail B'. Its flange then clears the rail A', and is afterward carried gradually down to the proper level of the track. E and D are two safety castings which, in case of a train running out of the siding while the switch is open, guide the wheels to the main line. Casting E guides the flange of the wheel running over it laterally, and casting D elevates the flange of the wheel running over it to clear the rail A'. The curved rail C is fixed at one end and is movable at the other; it is connected to the rocking shaft of the lever L, so that when the switch stands open the rail C lies away from the rail A', and fits close to it if the switch is set for the siding. Its object is to set the switch right by the automatic action of the train in case the switch is "trailing," if by mistake it is set for the siding. If in such case a train moves in the direction toward which the switch is pointing, the flanges of the wheels will force their way between the rail A' and the movable rail C, which being connected with the rocking shaft will throw it over, together with the weighted lever L, and thus set the switch for the main line. From the above it will be understood that as trains passing to or from the siding are subjected to rocking, on account of the elevation of one of the rails, a slowing up of the speed is necessary.

Trap's switch is a combination of the stub-end and the point switch. It is so arranged that the points of the tongues are held to fit against the stock-rails by volute springs (or by the elasticity of the rails), while their heels, together with the stock-rails, are moved to be set for either position.

Turn-Tables are platforms by means of which the engine or cars may be turned around. This is effected by excavating a pit under a portion of the track, and laying in the bottom of this pit a circular track, upon which a platform, supported by friction-wheels, is made to revolve. A great many plans have been devised to effect this object.

Turn-tables are generally made of wrought iron, but wood is also used in their construction. Cast-iron turn-tables are largely used in this country. Fig. 3598 represents a longitudinal section of such

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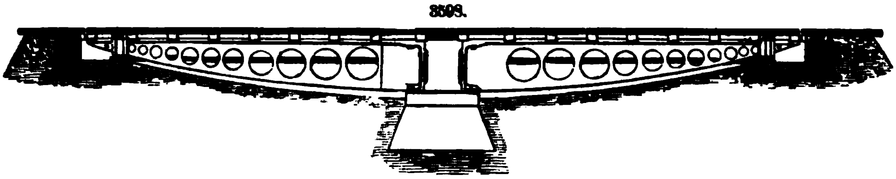

a table, which consists of four cast-iron arms or beams, secured to a cast-iron centre-box. In the centre of this box is placed the peculiar pivot upon which the table turns. (See vertical cross-section of the centre-box, Fig. 3599.) At the outer ends of the arms are cross-girts carrying wheels to swing clear of a circular track-rail, and upon which rail these wheels rest when the table tips, but they swing clear of it in turning. In the centre of the pit is placed a conical centre-post, with a broad base resting on a firm foundation of stone. This post extends nearly to the top of the centre-box. The top of the post is made hemispherical, and on it rests a cast-iron cap, carrying a set of steel plates grooved and filled with conical steel rollers. The whole weight of the table and engine rests on these steel rolls in turning. A cap of cast iron rests on the top steel plate, and to this cap the centre-box is suspended on a circle of bolts, with a layer of wood between the box and cap. By taking out this wood, thinning it, or adding more to it, the table can be adjusted in height. Upon the arms cross-ties are laid, and to these ties rails similar to those on the road are secured. The pit is usually built with a curbing of stone, and in the centre is built a strong foundation of a size suitable to carry a top stone. The pit is deepest in the centre, and grows shallower toward the circumference, ending in a level plateau for the reception of the circular track. This track, carefully leveled, rests on well-laid sills—stone or iron preferable to wooden sills. One man, with a lever of such a length as will extend over the curbing of the pit, can with ease turn the heaviest engine on this table. If steel is used for the centre-plates and rollers, the table turns more easily and is more durable. The rolls ought to be oiled, and if cleaned at least every three months they are very durable. In regard to diameter of table to suit any particular case, the larger diameters are the best, as the engine, either with empty or with full tender, can be most readily balanced; and it is necessary that the centre of gravity of the load be in all cases brought over the centre of the table, so as to have no appreciable weight on the circular track.

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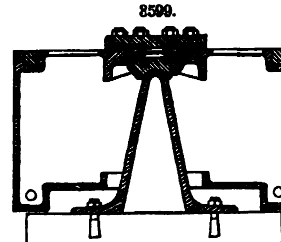

Traverse-tables are low carriages or platforms mounted on small wheels, which run on rails laid perpendicular to the line of road. Two rails laid on these platforms, forming an elevated portion of the track, receive a car which is to be transferred to another track. The rails on which the platform moves may be laid temporarily on top of the rails of the road; or, as is most commonly the case, the table moves on a railway of its own laid in a pit, so that the surface of the table is on the level of the track. Traverse-tables are chiefly used in car-shops and in buildings where cars are kept when not in use.

A Car-Replacer is a device for replacing cars, locomotives, etc., accidentally off the track. The replacer made by the Pennsylvania Steel Company, and represented in Fig. 3600, consists of a pair of double inclined planes, with hooks for securing them to the track, and provided with rails to guide

the wheel inward to the track. The base of the inclined planes lies on the cross-ties, and the surface rises from the base at each end toward the centre, so that cars can come on from either direction. Each plane is provided with rails of suitable design to receive the wheels. The one (A) which is to take the wheel that is inside of the track has a rail for the flange of the wheel to run on, and raises the wheel high enough to carry the tread of the wheel on to the rail; the plane (E) that is to take the wheel that is outside of the track has a rail (I) for the tread of the wheel to run on, carrying the wheel high enough to take the flange over the rail. The surface of the planes is covered with wrought-iron plate, and the rails are of steel.

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EXPERIMENTS UPON PERMANENT WAY.—A long series of experiments on the stability of permanent way were made in Germany by Baron von Weber. (See "Die Stabilität des Gefuges der Eisenbahn-Geleise, von M. Freiherr von Weber," Weimar, 1869; *Engineering*, x., 264; *Railroad Gazette*, ii., 1870.) They are strikingly demonstrative of the small amount of stability, which, to use the author's own words, is so small in proportion to the disturbing influences brought to bear upon it, that almost any one of these influences would destroy the structure if it were not that the very load itself (that is, of the trains) increases the stability through the agency of the friction between the wheels and rails. In Baron Weber's opinion, the tendency of advanced railway practice is to abandon the ordinary system of iron or steel rails fixed on wooden sleepers for the use of permanent-way structures formed of iron alone; and he considers that ultimately lines of rails will be constructed as continuous girders, strong enough to resist all the actions of the rolling stock, and resting directly upon properly prepared ground, without the intervention of intermediate members of perishable materials. The characteristic structure of the permanent way has not changed much since the time these experiments were made. Valuable information can be had from the data deduced, full details of which will be found in the works above named.

Works for Reference.—"Manual for Railroad Engineers and Engineering Students," Vose; "The Field Practice of Laying out Circular Curves for Railroads," Trautwine, Philadelphia, 1872; "The Civil Engineer's Pocket Book," Trautwine, Philadelphia, 1872; "Permanent Way, Rolling Stock, and Technical Workings of Railways," Couche, translated by J. Edwards Wilson, London, 1879; "Handbuch für Specielle Eisenbahn-Technik, von Edmund Heusinger von Waldegg," Leipsic, 1873, 1874, 1875, 1876; "Methods for the Computation from Diagrams of Preliminary and Final Estimates of Railway Earthwork," Wellington, New York, 1875; "The Economic Theory of the Location of Railways," Wellington, New York, 1877; "Railway Appliances," Barry, London and New York, 1876; "The Road-Master's Assistant and Section-Master's Guide," Huntington, New York, 1879. See also the following periodicals: *Railroad Gazette*, New York; *Railway World*, Philadelphia; *Railway Review*, Chicago; *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden; *Revue Générale des Chemins de Fer*, Paris; *The Engineer*, London; *Engineering*, London. T. F. K.

RAILROAD CARS. PRINCIPLES OF RUNNING GEAR.—The essential features of the construction of railroad cars, differentiating them from vehicles used on common roads, are: 1, the wheels, which have flanges to keep them on the track; 2, the conical tread of their wheels, so made in order to diminish the resistance on curves; 3, the location of the axle-bearings outside of the hubs of the wheels, in order to facilitate a constant and perfect lubrication of the journals and an easy exchange of worn-out bearings by new ones, necessitating the rigid attachment of the wheels to their axles; 4, the location of the wheels under the car-body, so that its width may not be limited by the gauge of the track.

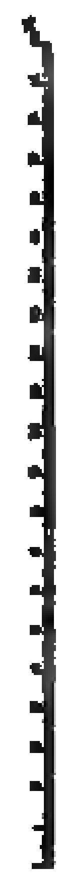
The sharpness of railroad curves puts a limit to the length of the rigid wheel-base of a car, and consequently to the length of the car itself. The difficulties arising from this have been largely obviated in this country by applying trucks, by means of which the total wheel-base of a car is divided into two short wheel-bases, mutually independent. An arrangement by which the axles can take a radial position on a curve, and yet not easily lose their common parallelism on a straight track, has also been made.

The dependence of the relative movement of two wheels fastened rigidly on one axle prevents easy running on curves, as it causes a longitudinal slip of the wheel traveling on the outer rail of the curve, this rail being longer than the inner rail. To obviate this, the treads of the wheels are made conical, so that the outer wheel, with its flange closer to the rail on a curve, runs on a larger diameter than the inner one. If the wheel is properly coned with relation to the curve, no longitudinal slip will take place; but as all railroad curves are not of the same radius, no one wheel can be adjusted to fit all. In practice axles are never independent of each other. Two or more are usually held rigidly connected by a frame, and thus the advantage of the forward outer wheel running on a larger diameter on a curve is somewhat diminished by the rear outer wheel running on a smaller diameter. The conditions that should be fulfilled, in order to make the movement of cars on a curve as easy as on a straight line, are: 1, the radial position of each axle; 2, the transformation of every pair of wheels into a cone, the summit of which is the centre of the curve; 3, destruction of the centrifugal force, independently of the reaction caused by the elevation of the outer rail; 4, coupling of the cars such that the force exerted on the draw-bar shall in no way influence the position of the wheels relatively to the track. The two wheels of the same axle are sometimes arranged to revolve independently of each other, in order to avoid the longitudinal slip made by the wheel rolling on the outer rail of a curve. But devices of this kind are seldom used, as railway rolling stock has to be constructed so as to run to the best advantage on a straight track, which

requires parallel axles and cylindrical wheels. The distance between the extreme rigid axles of a car is a very important factor in the curve resistance, and is limited by the sharpness of a curve. The shorter the rigid wheel-base, the more easily will the car run on a curve; but practice has shown that placing the axles as close together as the wheels will admit (the trucks of American rolling

3601.

3602.



stock were formerly so made), although favorable to the movement on curves, produces great oscillations on a straight line. On European cars, where the axles are rigidly held in position by the frame of the car, the rigid wheel-base is considerably longer than on American cars, although the car-bodies

are shorter. The length of a European car is limited by the wheel-base, as too much of overhanging weight would not be favorable for stability; and the wheel-base is limited by the sharpest curves of the road. At a convention held in Dresden, the maximum lengths of wheel-base for cars running on roads with different curves were fixed by German engineers as follows:

Radius of curve in feet..	787 to 984	984 to 1,181	1,181 to 1.509	1,509 to 1,968	1,968 to ∞
Wheel-base..............	12 ft.	15 ft.	16 ft. 6 in.	19 ft. 8¼ in.	24 ft.

There is practically no limit to the length of the American car, the rigid wheel-base having no influence. The American car may be considered as consisting of two vehicles, each truck being a separate vehicle—the trucks being coupled through their centres by the frame of the car. There is thus a great difference between American and European rolling stock; and hence they are separately described.

AMERICAN RAILROAD CARS.

Railroad cars, according to the service which they perform, are divided into two principal classes —passenger and freight cars.

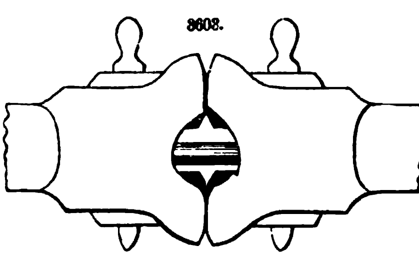
Passenger Cars.—The prime requisites of these cars are comfort and safety. The longer the car, or the further apart its points of support, the less are its oscillations; the greater the independence between the body of the car and its running gear, the smaller is the transmitted intensity of shocks caused by the roughness of the track and by a sudden change of the direction of running. In these particulars American cars surpass those of European construction.

A railroad car may be considered as divided into car-body, frame, coupling gear, running gear, and brakes. The last apparatus is treated in a separate article. (See BRAKES.) Figs. 3601 and 3602 are longitudinal and plan sections of the passenger car used on the Central Railroad of New Jersey.*

The Car-Body and Fittings.—The disposition of seats is such that there is one seat for every two passengers, and one window to each seat. The backs of the seats are reversible, so that passengers can always face the direction toward which the train moves. In the centre is a passage through the length of the car communicating by doors with the outside platforms, admitting thus an intercommunication through the whole train. On each side of a platform are steps. Ventilation is obtained principally by a special construction of the roof, which in its centre, through the length of the car, has an air space or channel called the "clear-story," on both sides of which are small windows and ventilators—the latter being openings (see *ee*, Fig. 3601) provided with slides or other arrangements to open and shut them. Often in the sides of the car-body itself, between but above the windows, are placed similar ventilators. Some cars have at each end, above the doors, a long rectangular aperture, which can be shut or opened. The roof of the car projects so as to cover the platforms, and is usually provided at its extremities with sheet-iron aprons, extending a few inches downward to prevent cinders and smoke from entering the car through the ventilators. The heating of cars is effected either by the ordinary iron stoves, placed one in each end of the vehicle; by air-heaters, which force the hot air to circulate through pipes placed a little above the floor on both sides of the car, with branches under every seat; or by hot-water apparatus (see HEATING BY STEAM AND HOT WATER). The lighting is accomplished by lamps, usually suspended from the roof, burning candles, oil, or gas, which last, in a compressed state, is carried in a metallic cylindrical tank, attached under the frame of the car.

The construction of the body of the car is exhibited in Figs. 3601 and 3602. The frame, which is always of wood and solidly connected with the car-body, consists of two longitudinal outside sills, which are connected at their ends by two cross-pieces, forming a rectangle which is strengthened by four inside longitudinal sills, and two iron truss-rods, *a a*. The truss-rods, through brackets and two wooden cross-pieces, support the frame in the middle. Iron rods, *b b b*, brace the frame laterally. The frame is supported on two wooden beams, called bolsters, *B B*, which are bolted to it and carry the centre-plates, *C C*. The bolsters are trussed by iron rods, *c c c*. The platforms, *P P*, are supported on separate frames, which consist of four longitudinal sills, two of which extend to the bolsters, as seen in the figures, and an end cross-piece. They are provided with foot-steps on both sides, and hand-rails. To them are attached the hand-brake spindles, *D D*. *E E* are the dust-guards, usually of leather, which cover the space between the platforms of adjoining cars, preventing the dust from rising from under the cars. These are not always used. The ordinary coupling gear consists of a wrought-iron draw-head *A*, which is attached between the two inside sills of the platform, and which performs also the duty of a buffer. Its construction will be understood from the illustration. The pulling or pushing force, exerted on the draw-head, is imparted to the car through a spiral or rubber spring *S*, which is placed between two iron plates, *p p*, the latter being held in position by two iron guides, *G G*, which are bolted to the sills. The draw-heads of two cars are coupled by a loose, shackling iron link *r*, which is held fast by pins. Fig. 3603 represents two draw-heads when coupled; the hole in the centre, through which the coupling link is seen, is a safety device to prevent injury to the hand of the brakeman during the coupling.

3603.



Miller's Safety Platform and Automatic Coupler is largely employed on American passenger cars. Fig. 3604 shows in the end view a longitudinal section and plan of a car provided with it, also views

* These and several of the succeeding drawings are taken from advanced sheets of the "Car-Builder's Dictionary."

3604

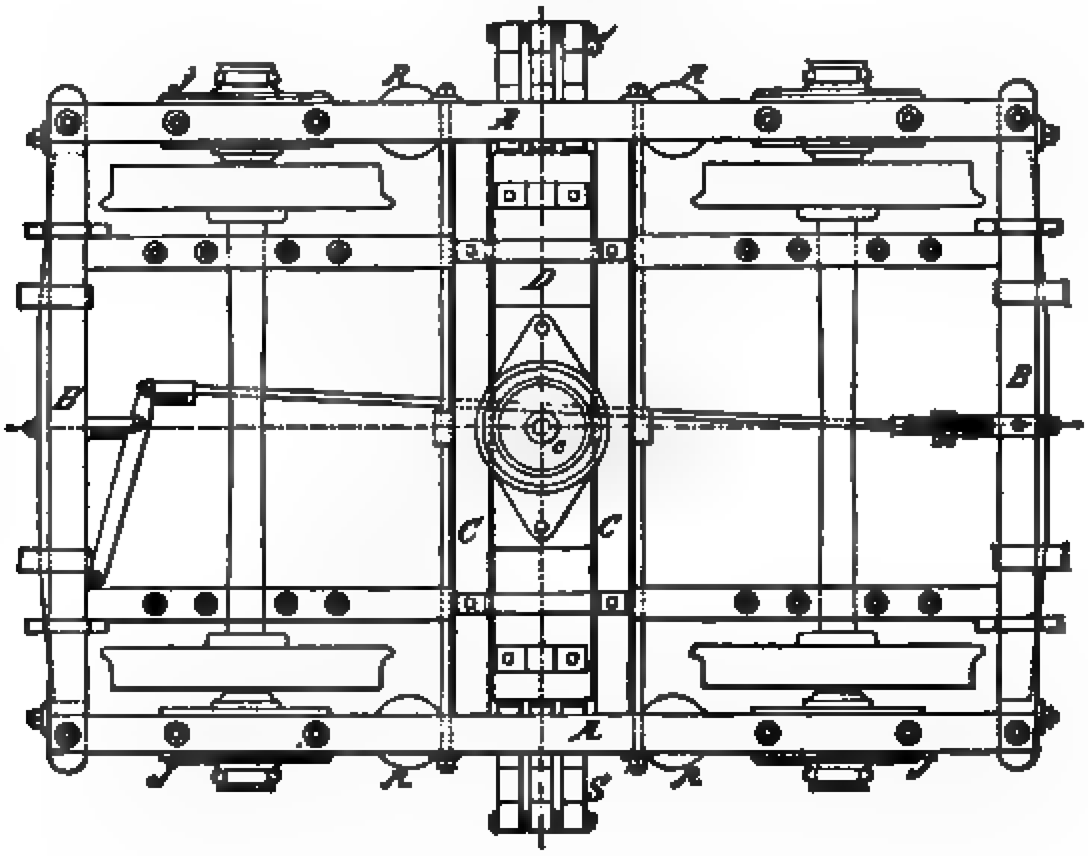
of the coupling hook and the buffer separately. This platform is placed in the centre-line of the main sills of the car, and is provided with a separate buffer *B*, acting on a spring *G*, which is adjusted in the same line. By this arrangement it is claimed that the so-called telescoping of cars in case of collision is less liable to take place than if the platforms were placed below the main sills, in which case one of the platforms can be easily broken off. The coupler consists of a hook *A*, attached to the draw-spring in a similar manner as the ordinary draw-head, and at the same height above the track, but in such a way that the outer end is free to move laterally a sufficient distance. The coupling hook projects beyond the platform. The stop *C* is to prevent accidental uncoupling. When two cars are brought together, the coupling hooks, from their shape, push each other aside, until the buffers *B* are compressed hard on the buffer-springs; then, the points of the hooks having passed each other sufficiently far, the hooks are carried forward by their main springs, and thus the coupling and compression are both effected automatically at the same time, and without the use of links and pins. When two cars are thus coupled together, the head of the hook of each car is under the buffer-beam of its opposite car, and the platforms are close together (about 4 in. apart). The effect of this is that one platform cannot be forced over the other. The compression makes the train run steadily, and prevents all jerking in starting and stopping. To uncouple the cars, it is sufficient to reverse the lever *D*, which is pivoted to the platform, and the lower end of which is connected to the hook by a chain.

3605.

Trucks.—The passenger car is supported on trucks, which are so arranged as to move laterally and around their centres independently of the car. The advantage of this is the reduced resistance to moving on curves, unaffected by the length of the car and the ease of motion or stability of the car-body. Passenger cars have either four- or six-wheel trucks. The former construction is shown in Figs. 3605 to 3608, representing respectively the side elevation (half in section), plan, lateral cross-sections showing the spring-gear, and end elevation, showing a half section through the axle-box. A wooden rectangular frame, *A A*, *B B*, rests on four rubber springs, *R*, of cylindrical shape; these are supported on two iron equalizers, *E E*, which are suspended on the axle-boxes placed outside of the wheels. The jaws *J* of the axle-boxes, the object of which is to guide them, are bolted to the frame, and are braced at the bottom by iron bars. The truck-bolster *D* rests between two wooden beams, *C C*, which are fastened to the frame and strengthened by iron truss-rods, as seen in the illustration, and on six elliptic sets of springs, *S S*, which are supported on cast-iron plates, suspended from the beams *C C* on hangers *H H*. A timber, *T*, joins the supports of the springs of the opposite sides, and prevents the falling of a spring under the wheels, should the former happen to break—for which purpose also the iron bands *b b* are attached, as seen in Fig. 3607. Between the ends of the bolster *D* and the truck-frame is a play which admits some motion to the bolster. A centre-plate *c* is attached to the bolster, which receives the centre-plate *C* (see Fig. 3602) of the car-body. A pin keyed under the truck-bolster, and passing through both the centre-plates, prevents the truck from separating from the car-body, in case of jumping the track; the check- or safety-chains (*s s*, Fig. 3601) serve for the same purpose.

The action of the truck will be easily understood. When the car enters on a curve, the front wheel, striking with its flange against the outer rail, will move the truck around its vertical

3606.

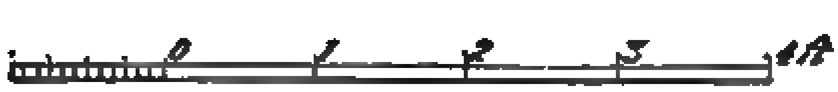


centre-line, bringing the four wheels into a convenient position on the curve; the tractive force which acts on the front coupling of the car, and the resistance of the subsequent cars which acts on

3607.

the coupling of the rear end of the car, tend to change the position of the car-body—the tendency being to change the curved line of the whole train into a straight line; this gives lateral forces which

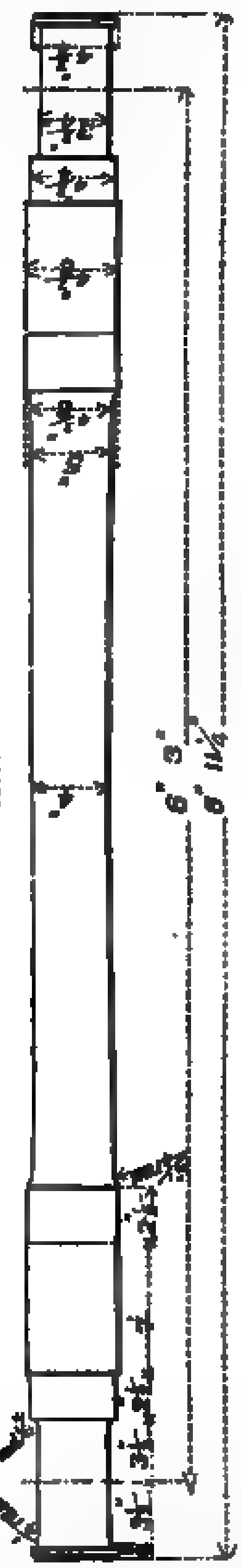
3608.



are imparted to the trucks through their centres, and which on that account do not define what position the truck under their influence may take. Practice having shown that it is advantageous to

neutralize these lateral forces, the swinging arrangement, as described, has been adopted. This gives freedom to the bolster, which through its centre-plate is fastened to the car-body, to move laterally, changing only the position of the hangers on which it is suspended, but not affecting the remaining part of the truck. Besides the centre-plates, there are still two other points of contact between the truck and the car-body, and these are so-called side bearings, *d d*, which are wooden or iron blocks attached to the truck-bolster. In contact with these are two other similar blocks attached to the upper or car-body bolster. They prevent any rocking of the car-body, but the chief and important object is safety. In case of breakage of one of the four wheels, the truck has a tendency to drop at one corner, while the diagonally opposite corner rises. The side bearings, however, keep both sides of the truck at equal heights, so that the truck can travel on three wheels. Another and not less important advantage of trucks is their neutralizing effect on all shocks imparted to wheels by running over rail joints and inequalities of the track. Iron bands attached to the wooden beams that are seen in the plan, fastened between *B* and *C*, prevent a broken axle from falling down. The manner of attaching a brake to the truck will be readily understood from the illustrations. The brake-blocks are bolted to wooden beams which are suspended from the truck-frames *B B*, on hangers; two stiff springs fastened to the

3609.



3610. 3611.

frame *B B* act on the brake-beams, keeping them and the blocks off the wheels. The side elevation and the plan show the arrangement of levers through which the power is transmitted from the brake-spindles to the blocks.

Car-axles are of wrought iron or steel, and their shape is represented in Fig. 3609. The dimensions are those adopted as standard by the American Master Car-Builders' Association.

Car-Axle Boxes.—In Figs. 3610 and 3611 are represented the longitudinal

3612.

section and end view (half in section) of a standard box adopted by the same association, which is the type commonly used in America. The bearing *b*, of a hard composition, rests on the top of the journal. A little play is left between the collars to allow of some lateral motion to the axle. A wedge *c*, as it is called, is a cast-iron plate, the object of which is to facilitate removal of the bearing without the necessity of raising the whole box. The lubrication of the journal is effected by placing cotton waste soaked in oil under the journal in the cavity of the box; a fresh supply of oil is poured into the box by the front opening, which is provided with a hinged door To prevent the oil from being carried out by the motion of the axle through the back opening of the box, a wooden or leathern collar *a*, which is usually made in segments held together by a steel wire, is placed on the axle between two ribs *b* of the box. The top of the bearing is slightly tapered from the centre toward both ends, the object of which is to admit of a slight change from the level position of the box. In order to prevent the wear of the brasses from the axle-shoulders, the Pullman Palace Car Company use the axle-box shown in Fig. 3612. *A* is the bearing, and *B* the wedge, which is provided at its front end with a vertical rib to which is riveted a brass plate *C*, in contact with which is the axle-collar *F*. The brass plate *C* prevents the wear of

the bearings from the lateral pressure. The wedge B is prevented from sliding out by a rib a cast on the box. f is a circular hole through which the bearing can be inspected.

A large number of axle-boxes have been patented, the benefits claimed by most of which are economy of lubricant and prevention of overheating. The axle-box, however, is still open to great improvements in the first particular. As regards heating, experiment has shown that the tendency to this is lessened by large journals, which reduce the pressure per square inch on the bearing. Efforts have also been made without much success to change the sliding friction of the journals into rolling friction by inserting cylindrical rollers around the journal, between the latter and the inside cylindrical surface of the box.

Car-Wheels.—American car-wheels are almost always made of chilled cast iron. Car-wheels are subjected to great strain and rough usage, and therefore require not only hardness of the tread (the cylindrical portion of their surface), but also great strength, and the metal of which they are cast must possess the quality of becoming hard when chilled, and yet be soft and tough if not chilled. The chilled portion—which is at the tread and flange—is usually five-eighths of an inch deep, but this can be increased if desired. The chilled portion of the metal—which is easily distinguished in a fracture by its bright steel-like color—should disappear gradually, so as to be thoroughly intermixed with the soft portion, as otherwise it could be easily broken off. Chilled cast-iron wheels are commonly cast in the shapes shown in Figs. 3613 and 3614, the first being called a double-plate wheel (in distinction from one which has a single plate between the rim and the hub, as used for light cars), and the second the spoke-wheel. Chilled-iron wheels are considered more economical in use than any other, though there is a lack of accurate data on the subject. It is safe to state that a 33-inch chilled wheel will run, on the average, 50,000 miles before it is worn out; and wheels of this kind are known to have run over 200,000 miles, and some are still running even after having performed that amount of service. There is every probability that the manufacture of these wheels can and will be greatly improved. See in this connection a description of the manufacture, etc., of chilled wheels, in the *Railroad Gazette*, 1877, pages 505, 515, 529, 539, under the title "Salisbury Iron."

3613.

3615.

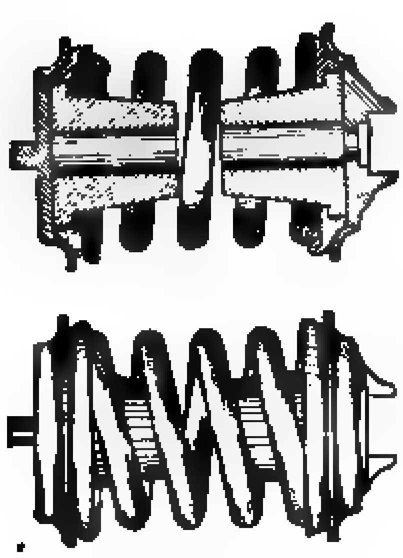
3616.

3614.

To reduce the wear of the tread of car-wheels, elastic substances are sometimes placed between the rim and the hub. Paper wheels have been successfully introduced in America, the construction of which is represented in Fig. 3615. Between the cast-iron hub and steel tire there is a mass of compressed paper inclosed between two sheet-iron disks. As seen in the engraving, this paper centre is, by means of flanges and bolts, securely connected to the tire and the hub. The bolt-holes in the tire are oval, and a play is left between the circumference of the disks and the tire in order to admit of a momentary compression and expansion of the paper. The paper is made of straw-boards about an eighth of an inch thick, which are pasted with rye-flour paste into sections about half an inch thick, when they are subjected for several hours to a pressure of about 400 tons, and subsequently dried in hot air; these sections are then pasted together in the same manner to give the required thickness of about 3½ inches. An old paper wheel was shown at the Centennial Exhibition in 1876, which had run under a Pullman car 312,900 miles without requiring its tire to be turned. The Atwood mastic wheel, represented in Fig. 3616, consists of a steel tire and cast-iron centre, between which a space, of the shape shown in black, is filled with hemp packing. The packing is forced, by means of a calking tool and a mallet, through an opening continuing around the wheel, which is afterward closed by a ring expanded in a dovetailed groove turned on the wheel-centre.

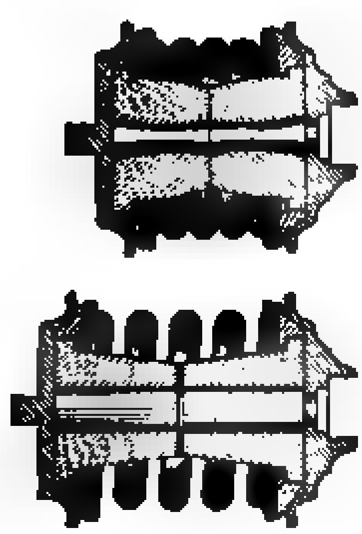
Car-Springs play a very important part in neutralizing the shocks to which the vehicles are subjected. Figs. 3617 to 3620 represent some of the newest and most approved forms made by the National Car-Spring Company of New York City. In these the object has been to meet an increase of load with a proportionate increase of power in the spring, so that an exact adjustment between the two is maintained. Fig. 3617 represents a spiral spring surrounding two rubber cylinders. Fig. 3618 shows the spring as compressed under light weight and under heavy weight, when the rubber

3617.



Elevation. Section.

3618.



Light Weight. Exhaust.

3619.

Elevation. Section.

3620.

Elevation. Section.

3621.

3622.

sustains the load. In Fig. 3619 the same principle is carried out by the use of two coiled springs in place of the rubber. The disposition of these is shown in the section. In Fig. 3620 both of the above systems are combined, the rubber cylinder being solid. Forms of elliptic springs, which also are largely used under railroad cars, are shown in the illustrations of car-trucks. A great number of springs have been patented for use under cars, many of which will be found illustrated in Knight's "Mechanical Dictionary."

SLEEPING CARS.—Figs. 3621, 3622, and 3623 represent respectively a longitudinal section, showing the interior plan and cross-section of a Pullman sleeping car, as constructed in this country for the Midland Railway of England. The car is divided by a central passage (as on ordinary American passenger cars), and on each side of the aisle are sections, each of which has two double seats, without reversible backs. The seats and their backs, or rather the upholstery with its frames, are removable, and can be arranged for a bed by placing the backs on the same level with the seats. The two opposite seats of each section form a lower berth. The arrangement of the upper berth will be understood best by examining the cross-section, from which it will be seen that the bottom of the upper berth is formed of a door, hinged to the side of the car at the bottom. By day this is secured in a diagonal position, as shown on the right of Fig. 3623, and at night it is dropped down horizontally, being held thus by two hangers. Two adjoining sections are separated by movable partitions, and a curtain conceals them from the passage; the bedding is kept in the closets formed by the bottoms of the upper berths by day, and also in boxes under the seats; for the linen are provided separate closets as shown in the plan. Each car is usually provided with one or two private state-rooms, and with dressing-rooms fitted with toilet appliances. The hotel car, which usually accompanies a train of Pullman cars on long journeys, is the ordinary sleeping car provided with a kitchen at one end, which is separated from the remaining part of the car.

Passenger cars for elevated roads in the cities usually have their seats arranged lengthwise, for economy of space and to give a wide passage for rapid exit from the car.

BAGGAGE, EXPRESS, AND MAIL CARS.—Short local trains have no separate car in which to carry passengers' baggage, but have one end of a passenger car, usually of the smoking car, partitioned off for that purpose. Trains which traverse a long distance require separate cars for the baggage, express matter, and the mail. These are constructed similarly to the passenger car, excepting that the car-bodies have either no windows or but a few small ones. Large sliding doors provided in the centres of both sides of the car serve for loading.

FREIGHT CARS.—Freight cars are divided into several kinds, according to the nature of the freight transported, and are known as box cars, stock cars, gondola cars, and coal cars. Excepting the coal cars, the differences between other freight cars are only in the construction of the car-body, which is either covered with wooden boards, so as to exclude light or air from the inside, or is provided only

3624. 3625.

3626.

with a skeleton framing, as in the case of stock cars. The construction of the body of a box car is made plain by Figs. 3624 to 3627. There are no windows, and the framing is covered with wooden boards on the outside, and also to half the height on the inside. The roof is shaped with straight lines, and has on its top, in the centre, a horizontal portion running along its whole length, which serves as passage for the brakemen. The brake-spindle is carried above the roof, where it ends in a hand-wheel. The admission into the box is gained from the sides, through the doors, sliding on the outside of the car; they are usually supported by one or two horizontal iron bars. Grain cars are provided also with inside doors, only of half the height of the box, which are hinged on a vertical rod; to open them, they are first raised upward and then swung open inside of the

box, in which position they are fastened. In the longitudinal section, Fig. 3626, these doors are shown opened.

The freight-car frame is constructed similar to that of a passenger car, and will be understood from the same illustrations. Iron frames have been used to a limited extent. These have the disadvantages of difficulty of repair, and of sustaining greater injuries than wooden frames in cases of collision. The frame-bolsters are made of wood or iron. When of the latter material, they consist of two flat bars, welded together at their ends and separated at the centre by castings. The centre-plate is bolted to them. Freight cars have no outside platform, and are coupled by the ordinary draw-bars. Many devices have been tried to make efficient and cheap self-couplers for freight cars, but none have come into general use. The draw-bar of the car illustrated differs from the ordinary device by the addition of a supplementary spring which diminishes shocks. A continuous draw-bar is sometimes used, consisting of the two draw-bars of a car connected by an iron rod, thus relieving the frame of the front car in a train from the enormous strain caused by the resistance of the following cars.

Freight-car trucks are usually made now of iron, and are always four-wheeled and of a simpler

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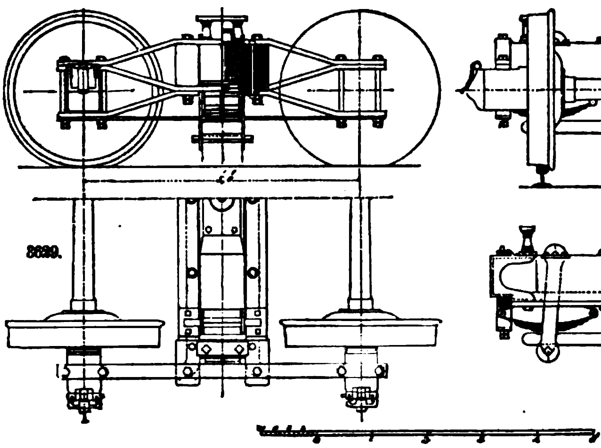
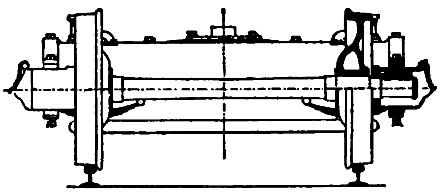
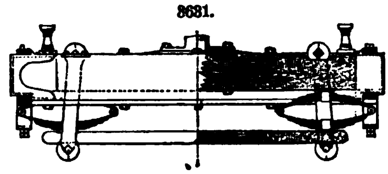
3629.



3630.



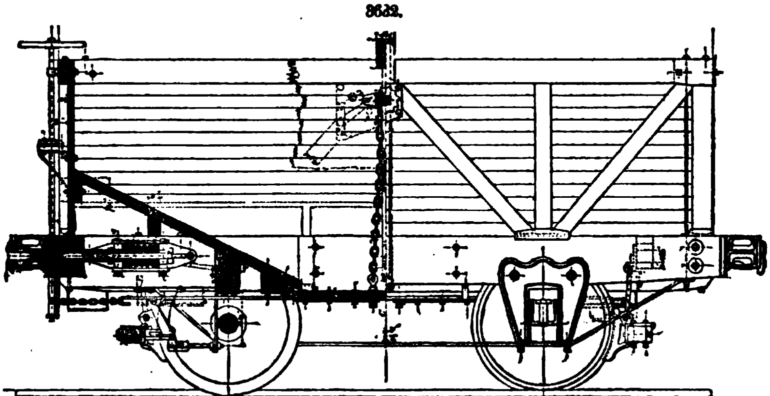
3631.



construction than those of passenger cars. In Figs. 3628 to 3631 is represented an iron freight car truck used on the New York Central and Hudson River Railroad since 1876. Fig. 3628 is a side elevation, half in section; Fig. 3629, half plan; Fig. 3630, an end view, showing section through an axle-box and half of the wheel; and Fig. 3631, two half cross-sections, showing the swing-gear. The frame consists of flat iron bars, trussed and bolted to the axle-boxes, thus dispensing with the jaw or guides which are used on passenger trucks. Each side of the truck has a separate frame, connected by wooden beams, between which, and in the centre of the truck, the bolster is suspended. The bolster, which is also of wood, carries the centre-plate and two side-bearings.

The *stock car* differs from the box car in its body or box being formed so as to admit air and light to the inside, a free space being left between the boards with which the body is covered. For small animals, the car-body is divided into two by a horizontal floor. The *gondola car* resembles the fore

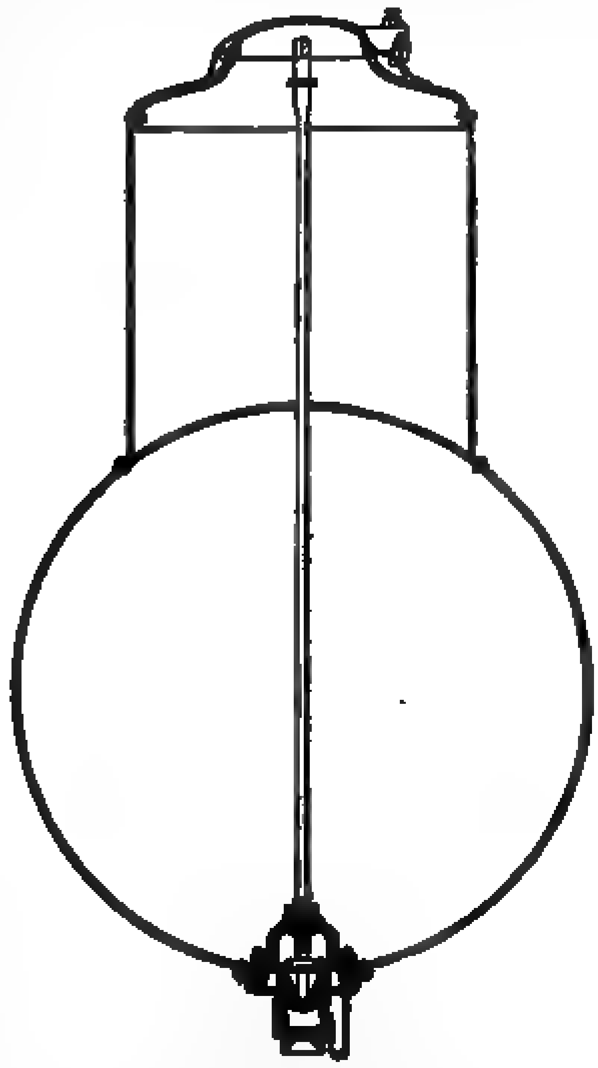
3632.



going, excepting that instead of the box it has low removable side boards and no roof. If it has no side boards, it is called a *platform car*.

Figs. 3632 and 3633 are a side elevation and end view (half in section) of a standard four-wheeled coal car of the New York Central and Hudson River Railroad. The axle-guards, or jaws, are bolted to the outside longitudinal sills of the frame; the jaws are supported on rubber springs, which are placed on the top of the axle-boxes. The floor has only a portion of its surface horizontal, toward which the outside portions incline; this horizontal portion constitutes the dump-door through which coal is discharged from the car. By this arrangement the discharge is almost instantaneous. The dump is suspended in a horizontal position by chains which are wound on an iron shaft, the latter being held fast by means of a ratchet-wheel and detent on the side of the car. Other details are easily understood from the illustrations.

3634.



3633.

The transportation of oil, which constitutes an important branch of the freight traffic in America, is accomplished either by the oil being transported in barrels in the open box or platform car, or in special oil-tank cars. The tank, a transverse section of which is shown in Fig. 3634, is of sheet iron, cylindrical in its shape, provided with a dome and Snyder Brothers' patented discharge-valve and man-hole fixtures. The valve-seat has a safety-cap screwed on the outside, which saves oil when the valve is not tightly closed. The valve is conical, and is attached to the end of a spindle whose point presses the valve down on its seat. The spindle is provided with a screw-thread, which turns in a nut that is fastened to the valve-seat; it ends at the top with a head which projects above the opening of the man-hole, and can be turned with a common wrench. The man-hole cover is hinged, can be screwed air-tight, and is provided with a padlock. The object of the dome is to furnish space for the expansion of oil.

3635.

Refrigerator cars are used for the transportation of fruits, meats, and other perishable articles, over long distances, and in all seasons of the year. Fig. 3635 represents the Tiffany summer and winter car. The body of the car is protected from the action of the sun's rays by a jacket composed of wooden boards, which incloses an air-space surrounding the car on its sides and the roof. This air-space is provided at both ends of the car with openings through which the outside air rapidly enters and exits before it becomes heated by the sun in summer; the openings being closed in winter, the air-space becomes a very efficient protector of the car-chamber from the influence of low temperature. The car-body (bottom, sides, ends, and roof) consists of three or more series of closed air-spaces, which are separated by partitions composed of thin ceiling boards and felt paper. Directly under the roof is placed the ice in summer, which, cool-

ing the air at the top, causes it to descend on the merchandise. Fresh air is admitted to the car by a regulated opening *C*, at the end of the car, and passes at first through tubes under the ice, where it is reduced to a proper temperature. The foul air of the chamber is forced up by the descent of the cold air and escapes into the air-passage of the outside jacket, through short pipes which establish the communication.

Freight trains are usually accompanied by a *caboose car*, also called conductor's car, which, as the latter name indicates, is for the convenience of the conductor. It is generally a short, four-wheeled car, with one platform at the end; it is provided with clear-stories, through the windows of which a view of the whole train can be had.

A *hand-car* is a small hand-propelling car, used by the trackmen. That represented in Fig. 3636 is provided with a countershaft carrying a pinion, which acts on a smaller pinion fixed on one axle. The revolving motion of the countershaft is produced by means of cranks and balance-levers.

The following table gives the principal dimensions and weights of American cars:

Table showing Weight, Dimensions, etc., of American Cars.

KIND OF CAR.	Gauge of Road.	CAR-BODY.			Length of Car Out to Out of Draw-heads.	Height of Car in Clr from Top of Rails.	Distance between Centres of Trucks.	TRUCKS.			Weight of Car Empty.	CAPACITY.	NAME OF ROAD OR MAKER.
		Length Outside.	Width Outside.	Height in Centre.				No. of Wheels in each Truck.	Diameter of Wheels.	Wheel-base.		No. of Passengers, Heads of Stock, or Weight of Load.	
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		In.	Ft. In.	Lbs.		
Passenger....	6 0	54 6	10 6	9 8	69 2	14 0	42 9	4	33	6 0	67,400	68 pass.	N.Y., L. Erie, and W. R.R.
	4 9	46 6	9 4	10 4½	58 0	13 10¼	28 0	4	33	6 6	39,300	54 "	Pennsylvania R.R.
	3 0	35–40'	8 0	8 6	40–45'	11 5½	.....	4	24	5 0	18,000	40-45 p.	Barney & Smith Mfg. Co.
	3 0	35 0	6 2	8 1	41 0	9 4	27 6	4	18	4 0	9,000	28 pass.	Billerica and Bedf'd R.R.
Baggage..	6 0	46 0	10 9	9 8	54 0	11 1½	24 9	4	33	6 0	34,750	10 tons	N.Y., L. Erie, and W. R.R.
	4 9	40 0	9 6½	8 1	46 6	11 6½	29 2	4	33	6 0	30,000	10 "	Pennsylvania R R.
	3 0	35 40'	8 0	8 6	40–45'	...	.....	4	24	5 0	14,000	... ..	Barney & Smith Mfg. Co.
Box....	6 0	30 0	9 0	7 0	32 0	11 4	19 0	4	28	5 6	20,510	12 tons.	N.Y., L. Erie, and W. R.R.
	4 9	28 4½	8 2	8 1	31 6½	11 1½	20 4½	4	33	4 10	20,000	12 "	Pennsylvania R.R.
	3 0	24 0	7 0	6 6	27 0	.....	..	4	24	4 0	... .	......	Barney & Smith Mfg. Co.
	3 0	22 0	6 2	6 7	26 0	8 2	17 4	4	18	4 0	[illegible]	.. ..	Billerica and Bedf'd R.R.
Stock...	6 0	30 0	9 6	7 1	32 0	11 5	16 7	4	28	5 0	19,000	16 h'ds.	N.Y., L. Erie, and W. R.R.
	4 9	28 0	9 0	8 1	31 6½	11 8½	20 4½	4	28	4 10	18,000	6–9 t.	Pennsylvania R.R.
	3 0	24 0	7 0	7 2	27 0	......		4	24	4 0	....	... ..	Barney & Smith Mfg. Co.
Platf'm.	6 0	30 0	9 0	....	32 0	4 0	19 0	4	33	5 6	17,960	12 tons.	N.Y., L. Erie, and W. R.R.
Gondola	4 9	31 6	9 0	....	31 8	......	22 6	4	28	4 10	19,000	12 "	Pennsylvania R.R.
8-wheel coal...	6 0	21 4	8 6	4 5	28 4	7 0	18 8	4	33	4 9½	14,950	12 "	N.Y., L. Erie, and W. R.R.
	4 9	20 9	8 0	4 0	21 11	7 6½	18 2	4	33	.. ..	16,000	12 "	Pennsylvania R.R.
	3 0	24 0	7 0	2 2	.....	......	... .	4	..	..	.....	.. ..	Barney & Smith Mfg. Co.
4-wheel coal...	6 0	11 6	7 8	8 8	18 6	6 2	.....	4	30	6 0	7,500	5 tons.	N.Y., L. Erie, and W. R.R.
	4 9	11 0	6 6½	4 0	.....	7 7	.....	4	33	5 0	7,900	5 "	Pennsylvania R.R.

EUROPEAN CARS.

European passenger cars are divided into three or four classes, the difference between which consists principally in the interior fittings. The fourth class, the lowest, found only on some Prussian and Russian roads, is either a roofless car, resembling a coal car, provided with benches, or a closed car, resembling an American box car, without benches or seats. Nothing less comfortable could well be contrived.

Each passenger car is usually divided into three, four, or five compartments, separated by partitions, either wholly or to half the height of the car, admitting of no communication between the compartments except from the outside, where running- or foot-boards are carried the whole length of the car, used almost exclusively by conductors, who, at the peril of their lives, walk from car to car collecting tickets. On each side of the car a door affords access to each compartment. These cars, having no end doors, have no outside platforms. A few roads, principally in Switzerland, Würtemberg, and Bavaria, have adopted a design which permits an intercommunication between cars, in the same manner as on American trains. There are some few combinations of the American and European types. The heating, on account of the shortness of cars and their division into compartments, has presented some difficulties, and new methods have been created by which it can be accomplished. In France, *chaufferettes* filled with hot water are employed. These are elliptical cylinders about 3 ft. in length, containing about 10 quarts of water, and are filled at certain stations, where special boilers are erected. The Eastern Railroad of France exhibited in Paris, in 1878, a third-class passenger car (see Fig. 3639), provided with a heating apparatus called *thermosyphone*, which consists of a cast-iron

boiler with inside furnaces, from which water heated to the boiling temperature forces itself through pipes into chaufferettes, which are placed in the centre of the floor in each compartment. After being cooled, the water returns back to the boiler through another series of pipes.

Figs. 3637 and 3638 represent the side elevation and plan of a first-class passenger car of the Eastern Railroad of France, exhibited in 1878 at the Paris Exhibition. It contains three compartments, in the centre one of which are placed sofas which can be converted into easy-chairs or beds, the three positions being shown in the plan.

3637.

Fig. 3639 represents the side elevation (half in section) of a third-class passenger car, which is divided into five compartments. It has a special apparatus for heating already described.

On the Western Railroad of France are two-story passenger cars, used only in summer. Admission is gained to the upper story by stairs placed at each end of the car. It is open at both sides, but covered at the top and ends; the seats are ranged laterally. This style of passenger cars originated on the Indian roads.

Sleeping cars are of many various designs, the differences being, however, only in the disposition of beds. Figs. 3640 and 3641 represent the longitudinal section and plan of a sleeping car on the Austrian state railways. The beds are not superposed and are placed longitudinally. At *A* are two compartments separated by doors, each for two beds; and at *B* are three compartments, each with one bed; *C* is the passage; *D*, seat for the servant; *E*, blanket-closet; and *F*, water-closet. Each compartment is provided with a separate washstand. The heating is accomplished by two hot-air furnaces, *b*, *d*, attached under the car as shown.

3638.

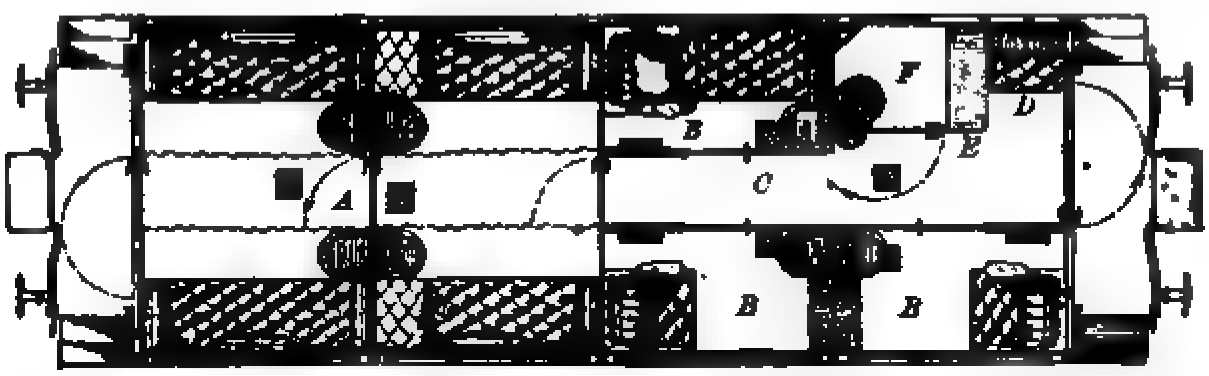
The body of European cars is an entirely separate part from the frame, with which it is connected by means of angle-iron and bolts. Iron is almost the exclusive material of which car-frames are made. An iron frame usually consists of: 1, two outside longitudinal sills of the I or [shape, to which are attached the axle-guards; 2, two end lateral pieces, of the [shape, which unite the longitudinal sills, and carry the buffers and the coupling apparatus; 3, two or more cross-braces of the I or [shape, which unite and stiffen the longitudinal sills at the intermediate points; 4, four diagonal braces of the I, [, or L shape, which are solidly joined with the end and the intermediate

cross-braces, and are usually placed on the top of the cross-braces and support the floor of the car-body. The coupling apparatus consists of a draw-bar, which is usually continuous and attached to the cross-braces of the frame through the intervention of spiral or elliptic springs. The draw-bars are coupled in various ways; usually they end with hooks, and have oblong rings attached to them, which hook on the draw-bar of the following car. These hooks are of complicated arrangement, and

are provided with screws by means of which they can be shortened. Two safety-chains complete the coupling apparatus. At the extremities of each car are two buffers, which consist of cast-iron casings holding spiral or rubber springs, against which the outside heads of the buffers press.

The running gear consists of two or three axles with outside journals. The jaws of the axle-boxes are of sheet or wrought iron, and are riveted to the outside longitudinal sills of the frame. The axle-boxes carry elliptic springs which support the frame. The frame is suspended on springs by

3641.



means of short knuckle-jointed links. The springs, especially those of the first-class passenger cars, are of great length. Car-axle boxes are usually made in two parts, upper and lower, which are bolted together. The bearings are of composition, and are separate as in American boxes. Boxes for liquid lubricants are arranged either to apply the oil from the top or from the bottom, or from the top and bottom. Axles are either of wrought iron or steel, and are shaped similarly to the American axles. The *Vereinbarungen* (Art. 159) gives the following dimensions for wrought-iron axles of a very good quality:

LOAD ON RAILS.	Maximum Diameter at the Hub.	Diameter of Journal.	Ratio of the Length of the Journal to its Diameter.
Lbs.	Inches.	Inches.	
8,250	3.977	2 244	1.75
11.000	4.4 8	2.994	to
14.800	5.600	3 293	2.25

The size of the axle-journals has a great influence on the economy of lubricating matter. According to the statement of Heusinger von Waldegg, those German railroad companies which adopted the largest journals on their axles have used in proportion the smallest amount of lubricants. Hollow axles have been tried in England, and also on the Continent, but have not been adopted.

European car-wheels are either provided with separate tires, or are of one piece; they are of wrought iron, steel, or cast iron with chilled tread.

Fig. 3642 represents a Krupp wrought-iron spoke-wheel, with a steel tire which is secured to the rim by bolts, as shown. A wrought-iron disk-wheel has a steel tire which is secured to the rim by means of two retaining rings bolted together, as shown in section in Fig. 3643. The novelty of this wheel is in the peculiar manner in which it is manufactured, as follows: A band of wrought iron of the width of the hub at one end is coiled up to form the hub, as shown in Fig. 3644; the band then becomes narrower, and when coiled around the hub forms the disk, and ends finally with a proper width to give the rim. The coil is then welded together and pressed to finished shape. Wooden disks for wheel-centres, fastened to the tire and the hub by means of rings and bolts, are also employed, and are said to be specially advantageous in cold climates, their flexibility averting the bad effects of a frozen ballast.

The rigid parallelism of the axles of European cars, preventing their free motion on curves, has been successfully overcome by a new system of running gear, invented by Mr. James Cleminson, which has been applied on some English railroads. It causes the axles to take automatically radial positions on curves, whatever their radius be. The diagram, Fig. 3645, represents this system, which consists of three separate two-wheeled trucks, the frames of which, *A*, *B*, and *C*, carry the axles, with their axle-boxes, guards, and springs. The car-body is supported by these trucks in such manner that the end trucks *A* and *C* can swivel freely around the central pivots *H H'*; while the middle truck *B* is at liberty to slide transversely to the car-body frame (shown in dotted lines) through a range equal to the versed sine of an arc the chord of which equals the total wheel-base.

3642. 3645.

The truck-frames are connected to each other by articulated radiating gear *I* and *K*. The action of this arrangement is as follows: When the car enters a curve, the centre truck *B* moves transversely, and causes the extreme trucks *A* and *C* to swivel around their centres, so that their axles assume positions radial to the curve.

European freight cars are constructed on the same system as the passenger cars, the difference being in the somewhat greater simplicity and rougher finish of details. They are divided into different types, according to the nature of the freight which they are to carry. General merchandise is carried either in closed freight cars, as represented in Fig. 3646, or in open cars, Fig. 3647. Fig. 3648 represents a coal car which discharges its load through side doors. A great proportion of the freight on European roads is transported in open cars, a water-proof sheet being used to protect the freight against the rain.

Iron is very generally used in the construction of freight-car frames on the continent of Europe. English builders have been rather slow in adopting it. It has the advantage of increasing not only the durability but also the carrying capacity of these cars. On the Emperor Ferdinand Railroad in Austria a combination of wood and iron is used, as stated, to great advantage. The iron construction, together with the decrease of weight of the car caused by the fact that no trucks are used, makes a European freight car much lighter in proportion than the American car.

Table showing Weight, Dimensions, etc., of European Cars.

KIND OF CAR.		Body. Length Outside.	Body. Width Outside.	Body. Height in Centre.	Length Outside of [illegible] Bars.	Height from Top of Rails.	No. of Wheels.	Diameter of Wheels.	Wheel-base.	Weight of Car Empty.	Capacity. No. of Passengers, or Tons of Load.	NAME OF ROAD AND REMARKS.
		Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		In.	Ft. In.	Lbs.		
Passenger.	1st class..	24 4¼	8 5½	....	29 9½	10 9¼	4	31½	15 0½	19,800	18 p.	Austrian State R.R.
	1st class..	25 7½	9 8	7 6¼	27 10½	11 5¾	4	41	14 9½	25,800	19 p.	French Eastern R.R. (1 sleeping compartment, see Fig. 3635).
	2d class..	28 4	8 5½	....	28 1	10 10½	4	30½	14 6½	21,010	32 p.	Austrian State R.R. (with brake).
	3d class..	28 4	8 5½	....	26 11½	10 10	4	33½	14 6½	18,260	50 p.	Austrian State R.R.
	3d class..	24 0½	9 2½	6 4½	26 3	10 5½	4	41	14 9½	20,680	50 p.	Fr'ch Eastern R.R. (see Fig. 3639).
Baggage		29 1½	8 7½	....	29 6½	10 6½	4	30½	14 6½	19,250	4.4 t.	Austrian State R.R. (with end outside platforms).
Freight.	Box.....	21 4½	9 0½	....	25 1½	11 2½	4	33½	12 0½	18,509	11 t.	Austrian State R.R. (see Fig 3640).
	Open	28 7½	8 2½	....	27 6½	....	4	39½	12 1½	11,440	12 4 t.	" " " (see Fig. 3647).
	Stock....	21 4½	9 0	....	26 11½	9 11	4	39½	12 0½	12,540	11 t.	" " " (without roof).
	Coal.....	15 9	8 11½	....	19 1½	8 0½	4	39½	8 3½	10,200	12.4 t.	" " " (see Fig. 3646).

Works for Reference.—"Voie, Matériels Roulants," etc., vol. ii., part i., Couche, Paris, 1870 (translated); "Handbuch für specielle Eisenbahn-Technik," vol. ii., Heusinger von Waldegg, Leipsic, 1875; "Car-Builders' Dictionary, prepared by a Committee of the Master Car-Builders' Association," New York, 1879; "The Pennsylvania Railroad," etc., Dredge, London, 1879; "On Car-Axle Boxes and Lubricants in Europe," *Railroad Gazette*, x., 389, 399, 400, 559; "Technische Vereinbarungen des Vereins Deutscher Eisenbahn-Verwaltungen," etc., Wiesbaden, 1871 (*Railroad Gazette*, v., 359, "Coaches and Cars"); "Die Schmiervorrichtungen und Schmiermittel des Eisenbahnwagen," Heusinger von Waldegg, Wiesbaden, 1866. See also files of the *National Car-Builder*, New York.

STREET CARS.—The cars which are used on horse railroads in cities differ materially from all other

3649.

3650.

forms of railroad vehicles. By far the larger proportion of all the street cars used in the world are of American design and construction. The present tendency is to build the cars light, thus economizing material and reducing the dead load to be hauled. Two examples of American street cars are given in Figs. 3649 and 3650, both of which are from the designs of the John Stephenson Company of New York, Mr. Stephenson having devoted many years to the perfecting of street-car construction. The class of car represented in Fig. 3650, though much used in Europe, is but little employed in this country. Street cars are made to be drawn by either two horses or one. One-horse cars are said to be more economical in use and to cause a saving in time of about 15 per cent. over two-horse cars. To enable street cars to pass the sharp curves common on city railroads, the wheel-centres are brought closely together, so as to leave considerable overhanging weight, which, owing to the slow speed at which the cars travel, does not materially affect their stability. One or two platforms are provided, from either of which the brakes may be worked. The axles are rigid, and have their journals outside the wheels. The upper portions of the wheels pass through the floor of the car and are encased. Spiral or rubber springs are placed above the axle-boxes, and on these the pedestals rest.

3651.

Fig. 3651 represents an improved form of car-spring, manufactured by the National Car-Spring Company of New York, for street-car use. The principle is the same as already described in referring to the springs constructed for steam-railroad cars The load first comes upon the outer spiral, and as it increases the resistance of the whole spring is augmented by that of the inner spiral, so that an exact adjustment is maintained.

The following are some dimensions, weights, and capacity of street cars as manufactured by the

John Stephenson Company: The lightest pattern car, with one or two platforms, with 10 seats (car-body 8 ft. long by 6 ft. wide), weighs from 2,000 to 2,600 lbs. Their capacity increases up to 22 seats—cars without top seats—and the dimensions up to 16 ft. of length and 6 to 7 ft. 6 in. of width, the weights varying, according to the pattern, from 3,300 up to 4,900 lbs. Cars with top seats—manufactured expressly for the European trade—can seat 22 passengers inside and 24 outside; their weights vary between 4,600 and 5,150 lbs. There are also summer or excursion cars, having open sides and only a light roof. Their capacity varies from 20 to 50 seats, and weight from 2,000 to 5,000. T. F. K.

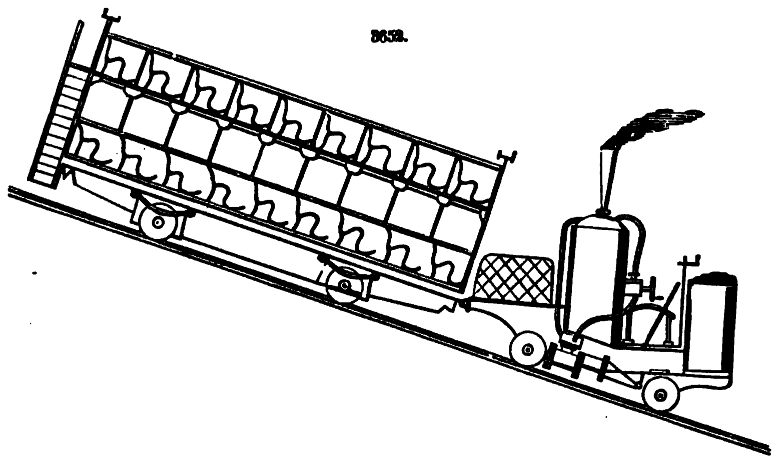
RAILROAD SIGNALS. See SIGNALS.

RAILROADS, MOUNTAIN. Railroads for the ascent of high mountains are specially constructed to enable the motor to obtain greater adhesion or a more positive hold upon the rails. The principal forms are centre-rail and rack-rail roads.

The centre-rail road has a third rail in the centre of the track, which is suitably grasped. The Mont Cenis road, which crosses the Alps between St. Michel and Susa, a distance of 48¼ miles, is thus constructed. It was built by Mr. Fell, and opened for traffic in 1867. The engines and carriages have each, in addition to the usual vertical wheels, four horizontal wheels, the flanges of which overlap and press upon the centre rail. Brakes are arranged to act upon all the wheels. This mode of construction was devised by Mr. George E. Sellers of Cincinnati in 1852, and first used by the Coal River Improvement Company in overcoming a grade of 150 feet to the mile in crossing the eastern barrier of the Shamokin coal basin. (See *Scientific American*, xvi., 53.) It has proved notably successful on Mont Cenis, although the grades are exceedingly steep, attaining in some cases a proportion of 1 to 12. An account of the trial trip on this road will be found in the *Scientific American*, xvii., 234.

Rack-rail roads are in existence on Mount Washington, N. H., and on the Righi, Switzerland. The Mount Washington railway is 2⅝ miles in length, and ascends a grade of 3,600 feet. The heaviest

3652.



grade is 13 inches to the yard, and the lightest 1 inch to the foot. The locomotive pushes the car before it up the incline, as shown in Fig. 3652, and both run upon three rails, the centre one being a cog- or rack-rail into which gears a cog-wheel on the locomotive.

The Righi line starts from Vitznau and rises up the mountain side to a station at Staffelhöhe. The length of the line is 3¼ miles, and the height of the upper terminus above the lower is 3,937 feet, being an average ascending gradient of about 1 in 4½. After leaving Vitznau, the grades vary from 1 in 5.56 to 1 in 4. This line was opened in 1873. (See *Scientific American*, xxix., 194.)

In the Wetli system of mountain railroad, instead of rack-rail and pinion, the locomotive is provided with a drum having a helicoidal thread, which engages with V-shaped mid-rails. This railroad was constructed over a distance of 9.6 miles between Wödensweil and Einsiedlen, Switzerland. The difference in altitude between termini is 1,513 feet. The system proved a failure in practice. (See *Scientific American*, xxxvi, 114.)

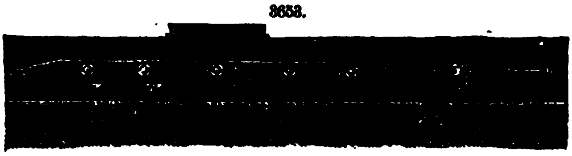
For rack-rail locomotive, see LOCOMOTIVES, CLASSIFICATION AND FORMS OF.

RAILROADS, PNEUMATIC OR ATMOSPHERIC. A distinction is sometimes drawn between so-called atmospheric and pneumatic railroads: the former being defined as consisting of a tube in which moves a piston to which the vehicles to be drawn are suitably connected, the said piston being impelled either by compressed air or by normal atmospheric pressure acting against a vacuum; and the pneumatic railway differing in that the vehicles themselves travel in the tube, which is made large enough for the purpose, and are impelled by the direct action of the blast. An example of one form of atmospheric railroad is given in Fig. 3653. It will be noted that the projection above the piston to which the vehicles are attached passes through a longitudinal slot in the pipe, which slot is opened and closed by suitable valves. In the construction of these valves, so that they shall be perfectly air-tight, and at the same time that they may freely open in front and in rear of the projection as it moves in the slot, lies the principal difficulty to be overcome in building roads of this

kind. A very full detailed account of about everything that has been done in this direction will be found in *Engineering*, xviii., 293 *et seq.*

The pneumatic road is employed only for the transmission of small packages. Extensive lines have been laid down in both London and Paris. (See PNEUMATIC DESPATCH.) An attempt was made to construct a pneumatic road in New York City large enough to contain passenger cars, and a small vehicle was impelled by an air-blast from an immense blower over a distance of a few hundred feet. The scheme, however, was found to be very uneconomical, owing to the large loss of power due to friction of the air in the pipes, and the difficulties of preventing leakage, and it was abandoned. An account of the machinery, etc., constructed will be found in the *Scientific American*, xxii., 154.

3653.



In 1864 Mr. F. A. Rammell of London constructed a tunnel 10 ft. high by 6 ft. wide and 600 yards long on the grounds of the Crystal Palace at Sydenham. A carriage holding 30 passengers was caused to traverse the tunnel by an air-pressure of two or three ounces to the square inch, the blast being given by a fan worked by a steam-engine. The same engineer also constructed a line between Euston Square and the Post-Office in St. Martins-le-Grand, London, a distance of about $2\frac{1}{4}$ miles. The tubes are 4 ft. 6 in. high, with an area of 17 sq. ft., and are of horseshoe-shaped section. The carriages weigh 22 cwt., and are 10 ft. 4 in. in length. About a ton of mail matter can be transported per minute.

RAILROADS, PORTABLE, are used by contractors in the construction of railroads, in mines, and also on sugar plantations, especially in Cuba. The so-called "contractor's track" is the invention of M. Peteler, and consists of sections, each about 25 ft. in length, made of two parallel timbers (usually 5 × 3 in.) held firmly by iron cross-tie rods. Half-oval iron rails, about $1\frac{1}{4}$ in. in width, are riveted on top of the timbers. The connection between the ends is effected by simple cast-iron locks. A gauge of 20 in. is found to be the most convenient for grading. Curves, turnouts, and switches are also made in separate sections. Portable tracks for use on plantations are usually of iron, and consist of sections made of two light rails weighing from 12 to 16 lbs. per yard. The rails are of the flat-footed pattern, are 10 ft. in length, and are connected laterally by four iron T-bars, which are riveted to the bottom of the rails. The flange of the T-bars, being directed downward, sinks into the ground, preventing the section from slipping.

Corbin's portable railroad has a wooden track, which consists simply of longitudinal pieces joined by cross-bars, and made in lengths of a size to be easily transported. It is especially designed for moving crops over soft or ploughed ground. The vehicles are small platforms having a pair of trucks at one end and a coupling at the other. The inventor states that with 10 trucks and 20 baskets, half of the latter being constantly in use, four workmen can pull and transport to a distance of 800 ft. 40 tons of beets or like vegetables per day. (See *Scientific American*, xxxi., 130.)

Joints of portable railroad sections are the subject of numerous patents. Pesant's joint, which is one of the best, consists of a hook riveted at the bottom of each rail at one end of the section. These hooks enter into corresponding slots made in a cross-bar riveted to the end of the following section, which bar projects somewhat beyond the ends of the rails. The hooks prevent any lateral or vertical displacement of the sections. T. F. K.

RAILROADS, STREET. The railroads which traverse the streets of cities may be divided into three classes: surface roads, or, as they are termed in England, "tramways"; elevated roads; and depressed or sunken roads.

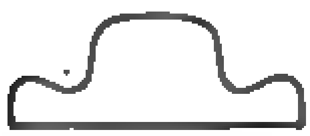
SURFACE ROADS.—The tramway proper consists of two parallel tracks of suitably smooth and hard material to receive the wheels, while the space between them, on which the animals drawing the vehicle travel, as well as the road surface on each side, is paved with different material. The wheel-tracks are usually of stone, occasionally of wood or iron. Stone tramways are in general use in southern Europe, especially in Turin, Verona, Milan, and other Italian cities. The stone track is granite, the slabs measuring about 2 ft. in width, 8 in. in thickness, and from 4 to 6 ft. in length. They are laid with close joints, and with 4 ft. 4 in. between centre-lines. Well-packed gravel foundations are employed. The first cost of the roads in Italy was about $8,600 per mile. They have been found most suitable for wide streets, and over short suburban lines with a large traffic. They last well and cost little for repairs. A horse can draw on a good stone tramway a load 11 times as great as he can move with the same effort and at the same speed on an ordinary gravel road, the force of draught being only $\frac{1}{179}$ of the load in the first instance, while in the second it is $\frac{1}{16}$. Even upon a very dry and smooth broken-stone road—i. e., a macadamized road in its best condition—the tractive power required is $3\frac{1}{2}$ to 4 times as great as upon a good stone tramway.

The street railway, as universally constructed, consists of rolled iron rails laid upon longitudinal timbers or stringers resting upon timber cross-ties. The stringers secure a uniform bearing for the rails, and raise them to the level of the street surface. Ordinary white pine is found to be a suitable wood. Stringers are usually sawed, the dimensions being 7 to 8 in. in depth, width equal to that of the rail, and length varying from 25 to 40 ft. The cross-ties are of any durable wood, either white or yellow pine, chestnut, or white oak, hewn or sawed 6 to 7 in. wide, 5 to 6 in. deep, and of such length as to reach about 12 in. beyond the stringers on each side. They are placed from 4 to 6 ft. between centres. Where streets are suitably sub-drained, cross-ties are simply laid in trenches excavated to receive them, the earth being well packed under and around them. It is generally best, however, to provide a foundation of gravel about 6 in. in depth. Considerable difficulty has been found in securing stringers to cross-ties. The plan commonly adopted is to spike the stringer directly

to the ties with long half-inch square spikes or half-inch round iron bolts; and to prevent spreading of the track, cast-iron knees or angle-irons are spiked to the stringer and to each tie or alternate tie.

The form of rail used on street railways differs, but it may be generally described as a flat plate having a ridge on the top. Fig. 3654 represents the section of rail used on the Third Avenue, Sixth

3654.



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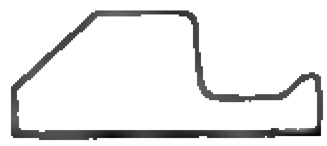

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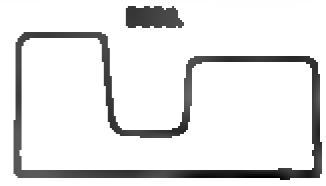


Avenue, Eighth Avenue, Broadway, and other principal railroads in New York. Its weight is 68 lbs. per yard, or 119.16 net tons per mile. Fig. 3655 is the form of rail used on roads having steam locomotives; this weighs 88 lbs. to the yard. Fig. 3656 represents a grooved rail, such as is used only on curves. Elsewhere they are disadvantageous, as they collect mud, ice, and dust, and tend to twist off the wheels of vehicles.

Rails are spiked to the stringers with half-inch spikes, each about 5 in. in length, and placed at intervals of 20 ft. Under the joints flat wrought-iron plates are inserted, to prevent bending or sinking of the rail ends. The ridge or top of the rail is either on the outer side or centre. For heavy traffic, street-car rails weigh from about 55 to 90 lbs. per yard; for light traffic, a weight of 30 to 35 lbs. has been found suitable. Frogs have either fixed or movable points. In the first case the horses pull the car over in the desired direction; in the second, the point, being pivoted, is moved by hand.

In England a grooved rail is preferred, and the road-bed is frequently made of concrete, cross-ties not being used, and stringers being replaced by cast-iron chairs. The gauge is maintained by connecting the chairs by iron bars. Mr. James Livesey has constructed a street railroad in Buenos Ayres (see *Engineering*, xlii., 328, 332) which is composed entirely of iron. The rail is supported by cast-iron blocks placed 3 ft. apart, and bolted to wrought-iron corrugated plates 6 in. in width, and resting on a stone foundation.

The best pavement between the rails, and upon which the animals appear to travel with greater confidence and less fatigue than upon any other possessing the requisite firmness and durability, is one of rather small cobble-stones laid with a very slight inclination from the centre toward the rails. The top of the pavement should be at the same height as the top of the adjacent edge of the rail. Horses should always be shod with flat shoes, rather broad at the heel and without corks. The frog should not be cut away, so that a portion of the weight shall come upon it whenever the animal treads upon an even surface. Upon street-railway lines, in consequence of the presence at all times of more or less dust and stiff mud upon the rails, the tractive force is comparatively large. In the average condition of the road, Gen. Q. A. Gillmore states that it may be set down as fully $\frac{1}{120}$ of the loaded car (see "Roads, Streets, and Pavements," New York, 1876); so that a car weighing 4,000 lbs., carrying 28 passengers, each weighing 150 lbs.—total, 8,200 lbs.—would require the exertion of a force of 68⅓ lbs. ($\frac{8200}{120}$) to move it on a level rail at a low speed. Upon descending grades of 1 in 68⅓, the brakes would not therefore have to be applied. On the Brooklyn (N. Y.) City Railroad 41 miles of track are operated and 1,950 horses employed. Each horse travels upon an average 16½ miles daily. The average rate of speed on New York City railroads is from 6 to 6½ miles per hour, including stoppages. Some valuable statistics giving particulars of New York street railways will be found in the report of the State Engineer and Surveyor of the State of New York for 1878; of Boston railways, in annual reports of the Massachusetts Railway Commissioners.

Many experimental attempts have been made to replace animal power by motors for the propulsion of street cars. Several of these machines will be found described under LOCOMOTIVES, FORMS OF. Comparison of the relative cost of animal power and that of traction engines is made by Prof. R. H. Thurston, in Reports of U. S. Commissioners to the Vienna Exposition, 1873, vol. iii., p. 94. For cars used on street railways, see RAILROAD CARS.

3657.

Wire-rope propulsion on street railways has been successfully put in practice in San Francisco by the Clay Street Hill Railroad Company. (See *Scientific American*, xxxii., 239.) The system consists in an endless wire rope placed in a tube below the surface of the ground, between the tracks of a railroad, and kept in position by means of sheaves upon and beneath which the rope is kept in constant motion by a stationary engine during the hours the cars are running. The power is transmitted from the motor to the rope by means of grip-pulleys, and from the rope to the cars on the street by means of a gripping attachment secured to the car, which passes through a narrow slot in the upper side of the tube. The road has a gauge of 3 ft. 6 in. An ordinary 30-lb. T-rail is used, which is set flush with the street. The rope runs at the rate of about four miles per hour, and the ascent of an average grade of 580 ft. to the mile is made (including stoppages) in about 11 minutes, the distance being 3,300 ft. The motive power is supplied by a 30-horse-power engine. An ingenious device for attaching the cars to the rope, invented by Col. W. H. Paine, C. E., is represented in Fig. 3657. (See also *Transactions of the American Society of Civil Engineers*, August, 1878.) This is so constructed as to allow the cars to start slowly, and gradually acquire the speed of the rope. *R* is the rope. At

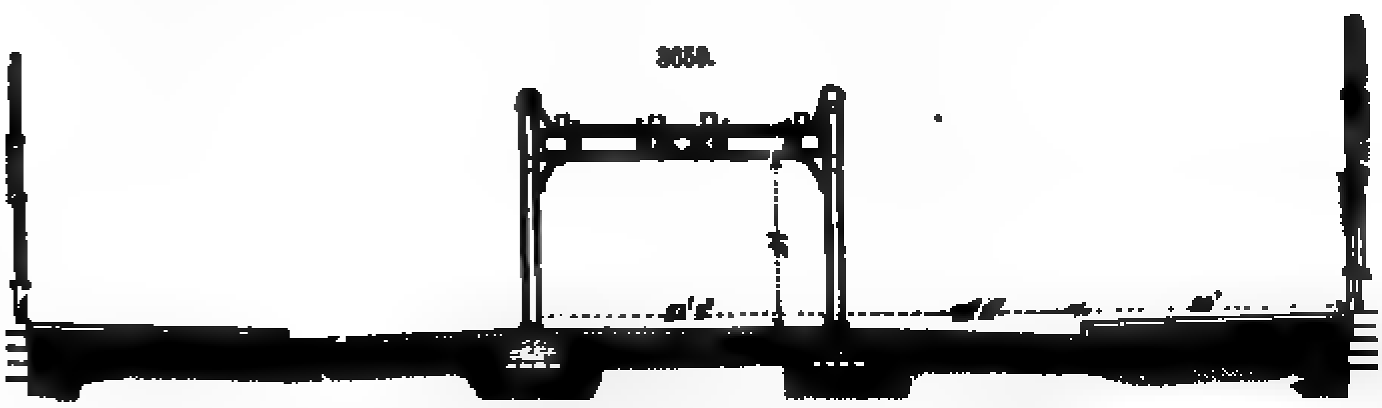
B B are two brakes operated by chains *c c*, which wind on the brake-spindle *A*. At *P P* are two grooved rollers, placed so as to embrace the rope. *L L* are two links connecting the brakes and rollers. The apparatus is secured under the car in a frame *F*. To start the car, the brakes are applied so as to press the rollers tightly against the rope, and the speed of the car is thus regulated

3658.

by the retardation due to the pressure. When the revolution of the rollers is wholly stopped, the car acquires the full speed of the rope.

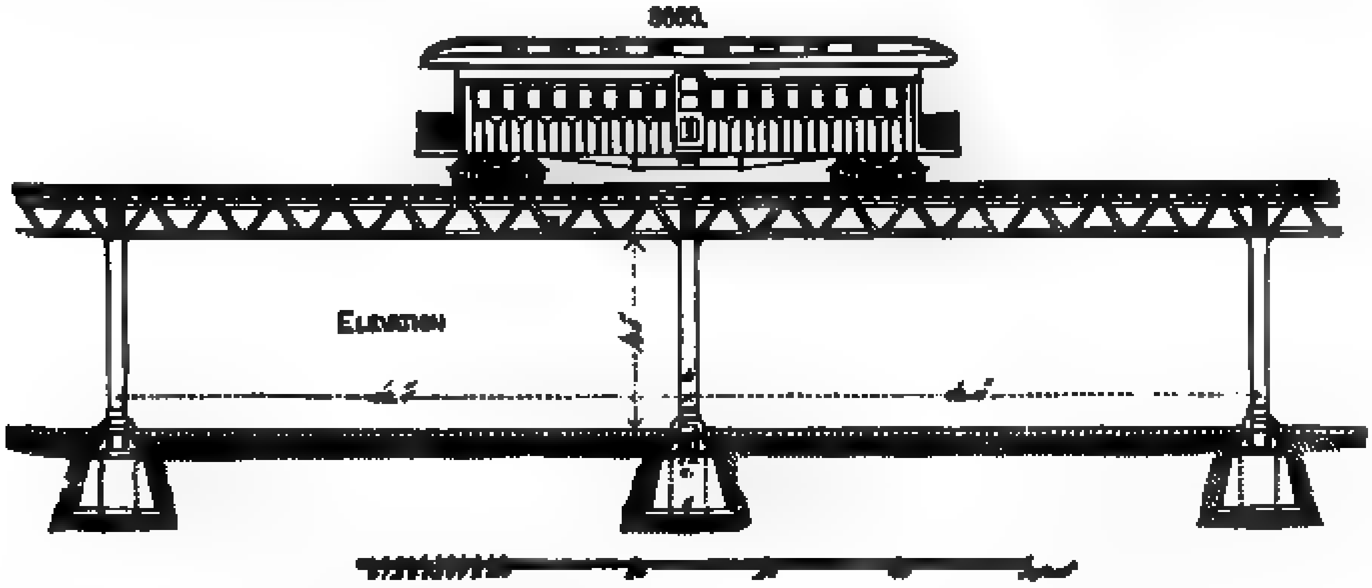
UNDERGROUND RAILROADS.—In London, England, the underground system of railroads has been in operation since 1863, when a section of $3\frac{1}{2}$ miles was opened. The track and rolling stock are

3659.



the same as on ordinary steam railroads. It traverses numerous tunnels (see TUNNELS) and open cuts. The main difficulty in its construction was the avoidance of the immense network of sewer-pipes which underlie the metropolis. The present length (1879) of all the lines is over 20 miles,

3660.



and the aggregate number of passengers carried annually is about sixty millions. A short underground railroad is also in operation in Constantinople, Turkey.

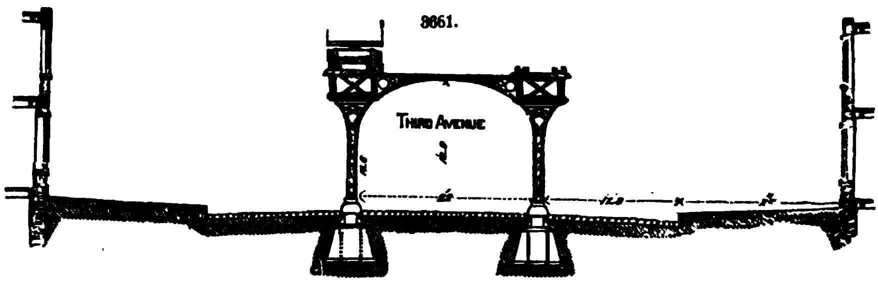
In New York City, the tracks of the railways which have their terminus at the Grand Central

Depot in Forty-second Street are sunk over a distance of 4½ miles, along Fourth Avenue. A detailed description of the construction of the various tunnels, cuts, etc., on this line will be found in the *Scientific American*, xxxi., 307 *et seq.* An effort was made to construct an underground railway along Broadway in New York, and a portion of the tunnel was opened in 1870. The scheme, at one time very promising, was killed by the inefficiency of its management, the engineering difficulties attending its construction, and the opposition of property-holders along its line.

ELEVATED RAILROADS.—Rapid transit has been secured in New York by the construction of lofty iron bridges, upon which the tracks of steam railroads are laid. Two systems of structure have been adopted. That used on the Metropolitan road, running through Sixth Avenue, etc., is shown in side elevation and cross-section in Figs. 3658 and 3659, in which the upper structure consists of lattice-girders supported by iron columns, and extending across the street. The foundation for the columns consists of a bed of concrete spread about 6 ft. below the street surface, on which are laid heavy flagstones supporting a brick pier 4 ft. high. A cast-iron base for the columns, fastened by four 2-inch foundation iron bolts, is placed on top of the brick pier, which is 4 ft. square

The second system, adopted on the various lines of the New York Elevated Railroad Company, is represented in side elevation and cross-section in Figs. 3660 and 3661. The columns are placed

3661.



immediately under the track, each track forming a separate structure, connected at intervals by iron arches, as shown in cross-section. The foundation is similar to that of the other road.

The track is of the standard gauge. Rails weighing 50 lbs. are laid on wooden cross-ties, and on each side of the rails are placed guard-timbers which are securely bolted to the cross-ties. The ties are secured to the longitudinal girders by bolts. (For detailed descriptions, see *Railroad Gazette*, 1877, p. 434, and 1878, pp. 78 to 120.) T. F. K.

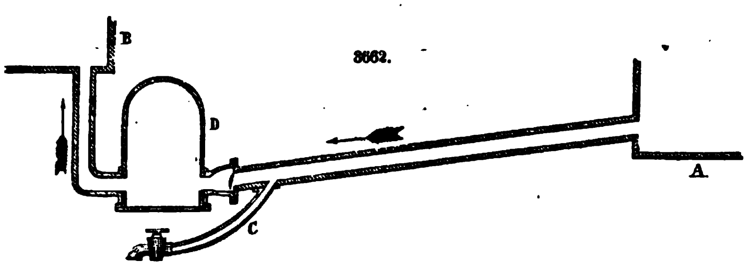
RAILS. See RAILROAD.

RAKE. See AGRICULTURAL MACHINERY.

RAM, HYDRAULIC. The hydraulic ram raises water on the following principle: A quantity of the liquid is set in motion through an inclined tube, and its escape from the lower orifice is made suddenly to cease, when the momentum of the moving mass drives up a portion of its own volume to an elevation much higher than that from which it descended.

The first person who is known to have raised water by a ram, designed for the purpose, was Mr. Whitehurst, a watchmaker of Derby, in England. He erected a machine similar to the one represented in Fig. 3662, in 1772. *A* represents the spring or reservoir, the surface of the water in which

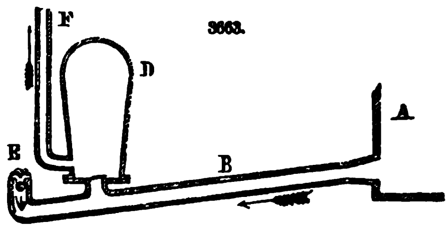
3662.



was of about the same level as the bottom of the cistern *B*. The main pipe from *A* to the cock at the end of *C* was nearly 600 ft. in length, and of 1½-inch bore. The cock was 16 ft. below *A*, and furnished water for the kitchen offices, etc. When it was opened the liquid column in *A C* was put in motion, and acquired a velocity due to a fall of 16 ft.; and as soon as the cock was shut, the momentum of this long column opened the valve, upon which part of the water rushed into the air-vessel *D* and up the vertical pipe into *B*. This effect took place every time the cock was used; and as water was drawn from it at short intervals for household purposes, "from morning till night—all the days in the year," an abundance was raised into *B* without any exertion or expense.

The *bélier hydraulique* of Montgolfier was invented in 1796. Although it is on the principle of the one just described, its invention is believed to have been entirely independent of the latter. Fig. 3663 represents a simple form of Montgolfier's ram. The motive column descends from a spring or brook *A*, through the pipe *B*, near the end of which an air-chamber *D* and rising main *F* are attached to it as shown. At the extreme end of *B* the orifice is opened and closed by a valve *E*, instead of the cock in Fig. 3662. This valve opens downward, and may

either be a spherical one, as in Fig. 3663, or a common spindle one, as in Fig. 3664. It is the play of this valve that renders the machine self-acting. To accomplish this, the valve is made of or loaded with such a weight as just to open when the water in B is at rest; i. e., it must be so heavy as to overcome the pressure against its under side when closed, as represented in Fig. 3664. Now suppose this valve open as in Fig. 3663: the water flowing through B soon acquires an additional force that carries up the valve against its seat; then, as in shutting the cock of Whitehurst's machine, a



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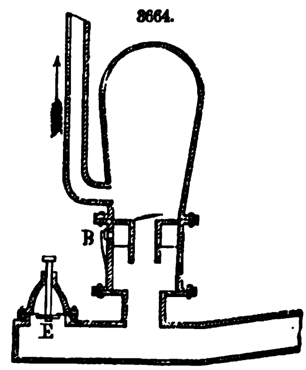


3664.

portion of the water will enter and rise in F, the valve of the air-chamber preventing its return. When this has taken place the water in B has been brought to rest, and as in that state its pressure is insufficient to sustain the weight of the valve, E opens (descends); the water in B is again put in motion, and again it closes E as before, when another portion is driven into the air-vessel and pipe F; and thus the operation is continued as long as the spring affords a sufficient supply and the apparatus remains in order. The surface of the water in the spring or source should always be kept at the same elevation, so that its pressure against the valve E may always be uniform; otherwise the weight of E would have to be altered as the surface of the spring rose and fell. When the perpendicular fall from the spring to the valve E is but a few feet, and the water is required to be raised to a considerable height through F, then the length of the ram or pipe B must be increased to such an extent that the water in it is not forced back into the spring when E closes, which will always be the case if B is not of sufficient length.

If a ram of large dimensions, and made like Fig. 3663, be used to raise water to a great elevation, it would be subject to an inconvenience that would soon destroy the beneficial effect of the air-chamber. If air be subjected to great pressure in contact with water, it in time becomes incorporated with or absorbed by the latter. This sometimes occurs in water-rams, as these, when used, are incessantly at work both day and night. To remedy this, Montgolfier ingeniously adapted a very small valve (opening inward) to the pipe beneath the air-chamber, which was opened and shut by the ordinary action of the machine. Thus, when the flow of the water through B is suddenly stopped by the valve E, a partial vacuum is produced immediately below the air-chamber by the recoil of the water, at which instant the small valve opens and a portion of air enters and supplies that which the water absorbs. Sometimes this *snifting-valve*, as it has been named, is adapted to another chamber immediately below that which forms the reservoir of air, as at B in Fig. 3664. In small rams a sufficient supply is found to enter at the valve E.

Although air-chambers or vessels are not, strictly speaking, constituent elements of water-rams, they are indispensable to the permanent operation of these machines. Without them the pipes would soon be ruptured by the violent concussion consequent on the sudden stoppage of the efflux of the motive column.

The literature in relation to the performance and proportions of hydraulic rams is not very extended. Some rules are to be found in Neville's "Hydraulic Tables, Coefficients, and Formulæ," and Morin's treatise "Des Machines destinés à l'Elévation des Eaux"; and a discussion by the builders and users of these machines, published in *The Engineer*, xl., xli., furnishes some interesting particulars. From these sources the following notes are compiled:

Let D = quantity of water used by the machine in a given time; d = quantity of water elevated by the machine in the same time; H = head of water under which the ram works; and h = height to which the water is lifted. Then the efficiency of the ram, or the proportion of the power of the water that is utilized, is $\dfrac{d \times h}{D \times H}$.

To illustrate, in an experiment made by Gen. Haupt with a hydraulic ram in 1866 (see Trautwine's "Engineer's Pocket-book"), the following results were obtained:

Head under which the ram worked	8.812 ft.
Height to which the water was lifted	63.4 ft.
Pounds of water used per minute	27.73
" " raised "	1.736

Hence the efficiency of this ram was $\dfrac{1.736 \times 63.4}{27.73 \times 8.812} = 0.45$, or 45 per cent. of the power of the water.

The efficiency of rams, in practice, varies between 30 and 90 per cent. of the power of the water, depending upon the speed at which the ram works, size and length of connections, and details of construction; and it is not possible to formulate all these elements with precision. From a number

of experiments on hydraulic rams made by Eytelwein, D'Aubuisson has deduced the formula for efficiency, $\frac{d \times h}{D \times H} = 1.42 - 0.28 \sqrt{\frac{h}{H}}$; and Neville has modified this formula to $d \times h = 1.2\,D \times (H - 0.2 \sqrt{H \times h})$. Morin, from his own experiments and those of Eytelwein, gives the formula, $\frac{d \times h}{D \times H} = 0.258 \sqrt{12.8 - \frac{h}{H}}$.

Rules of this character are, of course, of limited application, but they are useful in showing the duty that can be expected from hydraulic rams under average conditions. Experiments covering a wide range of proportions would be the most valuable guide for future practice. Unfortunately, there are comparatively few experiments on record, and scarcely any of these are completely detailed. A summary of experiments with hydraulic rams of modern construction is contained in the accompanying table:

Summary of Experiments with Hydraulic Rams.

NUMBER FOR REFERENCE.	Fall, from Source of Supply to Ram.	Rise, from Ram to Reservoir.	Pounds of Water used per Minute.	Pounds of Water raised per Minute.	Strokes of Waste-Valve per Minute.	DRIVE-PIPE, FROM SOURCE OF SUPPLY TO RAM.		DELIVERY-PIPE, FROM RAM TO RESERVOIR.		Per Cent. of Power of Water utilized.	Ratio of Height of Lift to Fall.	Ratio of Water used to Water delivered.
						Diameter.	Length.	Diameter.	Length.			
	Feet.	Feet.				Inches.	Feet.	Inches.	Feet.			
1	16	116	250	2.5	....	.....	......	....	....	72.5	7.25	10
2	23.5	203	139.8	10.4	....	.....	......	....	1,710	64.2	8.64	13.4
3	9	85	280	27.9	44	.....	70	1	250	83.7	8.89	10
4	50	123	40	12.5	120	.875	300	....	....	76	2.46	3.2
5	1.5	20	47.5	2.5	63	1.125	18.5	....	....	70	13.3	19
6	8	66	59.49	6.69	....	2.5	62	1.06	....	92.7	8.25	8.9
7	7	200	94.7	2.7	....	2	80	1.06	....	81	28.57	35.1
8	5.5	24.2	12	2.14	....	.....	......	....	....	78	4.4	4.6
9	4	96	420	11	....	.....	......	....	....	62.5	24	38.2
10	6	120	420	12	....	.....	......	....	....	57	20	35
11	10.5	96	92.97	5.87	....	.....	......	....	....	58.7	9.14	17.8
12	8.812	63.4	27.78	1.736	170	1.5	15	.75	200	45	7.2	16

The hydraulic rams ordinarily furnished by makers can be used with delivery-pipes from 800 to 1,000 ft. in length, and drive-pipes from 25 to 50 ft. long; and, according to statements in manufacturers' catalogues, when properly set will deliver about one-seventh of the water used to an elevation 10 times as great as the fall from the source of supply to the ram, one-fourteenth of the water used to a height 20 times as great as the fall, and so on in that proportion. The following table gives the proportions adopted by well-known builders, which do not differ essentially from those of other makers:

Dimensions of Hydraulic Rams made by Rumsey & Co.

TRADE NUMBER.	U. S. Gallons of Water used by Ram per Minute.	Length of Drive-Pipe.	Diameter of Drive-Pipe.	Diameter of Delivery-Pipe.
		Feet.	Inches.	Inches.
2	1 to 2	25 to 50	.75	.375
3	2 to 4	25 to 50	1	.375
4	4 to 8	25 to 50	1.25	.5
5	6 to 14	25 to 50	2	1
6	12 to 25	30 to 50	2.5	1.25
7	30 to 60	30 to 50	4	2
8	40 to 120	30 to 50	6	2.5

The discussions on hydraulic rams published in *The Engineer*, previously referred to, contain a number of rules for proportions; and those given by Mr. B. Massey, which seem most suitable for general use, are appended:

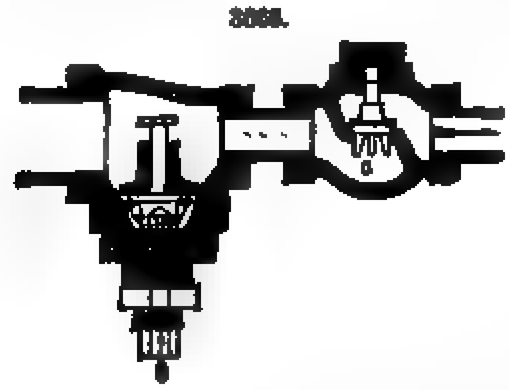
The size of the drive-pipe, at its junction with the ram, should be large enough to deliver three times as much water as is used, on the assumption that the water only flows about one-third of the time. It will be of ample size if it has the same diameter as a pipe 3 ft. long that will supply three times the quantity of water required under a 6-inch head. The length of the drive-pipe, to secure the best results, should be, for each foot of fall, 9 ft. with a fall of 2 ft. or under; 8 ft. with a fall between 2 and 3 ft.; 7 ft., between 3 and 4 ft.; 6 ft., between 4 and 5 ft. The delivery-pipe should be of sufficient size to deliver the required quantity of water with not more than 2 or 3 ft. of friction-head. The area of the waste-valve should be four times the area of the drive-pipe.

In Figs. 3665 and 3666 is represented a hydraulic ram manufactured in 1878 by the I. P. Morris Company of Philadelphia, for the purpose of irrigating the higher lands of a coffee plantation in South America. The capacity of this machine is larger than that of any hitherto constructed. The following data were furnished by the purchaser with his order: height of fall, 9 ft. 10 in.; elevation of reservoir, 63 ft. 10 in.; diameter of inlet-pipe, 11¼ in.; length of do., 52 ft. 4 in.; diameter of ascension-pipe, 5½ in.; length of do., 127 ft. 8 in.; diameter of waste-valve, 11¼ in.; contents of air-vessel, $4\frac{3}{10}$ cub. ft. The capacity of the air-vessel was increased to 5¼ cub. ft., as the additional expense of the material was amply compensated by the known advantage of a large air-cushion in partially relieving this type of machine from the violent shocks inseparable from its action. The following description is from the *Journal of the Franklin Institute:*

"The body of the ram is a cylindrical pipe, 11¼ in. bore and 1¼ in. thick, strengthened with flanges. It curves upward at the rear or discharge end until the axis of bore becomes vertical, when the bore is enlarged to 19¼ in. so as to form a chamber for the waste-valve. Several vertical ribs join the flange provided for the valve-seat at top of chamber with the main body of the ram. About midway the length of the body is the seat for the water-valve and the air-vessel. A horizontal flange on each side of the body, strongly ribbed, serves to hold the machine to timbers which rest upon stone foundations. Six bolts pass through all, with keys and plates at lower ends. The water-valve is of India-rubber, and seats upon a grating cast on the body of the ram, and is held in position by a stud carrying a guard. This valve is encased by the air-vessel, and access is had to it through a door. The body of the waste-valve is of cast iron, strongly ribbed, and is guided at its upper end by wings sliding within the bore of the valve-seat, and at its lower end by a stem working in a hole bored in the body of the ram. This hole is fitted at its lower end with a long tap-bolt, which is used to adjust the drop of the valve and the number of beats per minute at such a point, found by trial, where best efficiency of the ram is obtained. A piece of rubber interposed between the ends of stem and tap-bolt serves to soften the blow of the descending valve. The face of the waste-valve is a ring of wrought iron riveted to the valve, with three thicknesses of heavy sole leather between them, so as to give some elasticity, and thereby diminish the shocks given by the valve closing. The waste-valve seat is of cast iron, made heavy (about five times the weight of the valve), and firmly bolted to the body of the ram. The supply is carried through cast-iron pipes having socket-joints, and their thickness diminishes from 1¼ in. at the junction with the ram to five-eighths of an inch at the upper end. The ascension-pipe is welded wrought-iron tube, 5¼ in. diameter, joined by flanges. The apparatus for supplying air to the air-vessel is so made that the snifting-valve compels all the air admitted through it to enter the air-vessel; or if in excess, as in this case provided so, the surplus escapes between the under side of the valve-seat and the top of the screw-plug on which the valve is mounted, through an opening adjustable by means of the screwed shank of the valve-seat.

3665.

3666.



"The supply-air passes upward through the hollow shank, thence outward, through holes, into the space below the valve-seat; the valve-seat is perforated with several holes, through which the air rises and lifts the valve. When the valve closes, the return of any air is prevented; but if the seat be raised from the top of the plug, a portion of it, more or less as desired, passes between them and escapes. (See enlarged view of snifting-valve, Fig. 3666.) The valve is placed high enough to be above floods, and its operation is as follows: The tube *a* is of 1-inch gas-pipe, and it rises, from the point of its attachment to the body of the ram, to a suitable height, and carries the snifting-valve, Fig. 3666, and a check-valve; it is then joined by a half-inch gas-pipe, *b*, which descends and meets a check-valve attached to the ram immediately under the air-vessel. When the waste-valve opens, the water contained in the pipe *a* falls and produces a vacuum, when the air enters through the snifting-valve into pipe *a*. When the stroke recurs and the waste-valve closes, the water rises in pipe *a*, and displaces the air, which under pressure opens the check-valve *c*, whence it passes through pipe *b* and check-valve *d* into the body of the ram, and ascends into the air-vessel. This occurs each stroke, so that the supply of air is continuous. Any surplus is discharged by the modification before described."

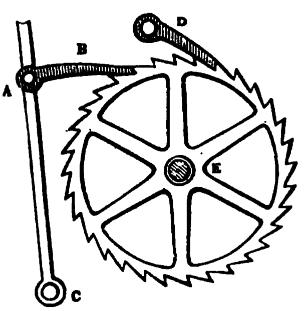
RANGE. See Stoves and Heating Furnaces.

RASP. See Files.

RATCHET-DRILL. See Drilling and Boring Machines.

RATCHET-WHEEL. A wheel provided with pins or teeth of a suitable form, and which receives an intermittent circular motion from some vibrating piece, is called a *ratchet-wheel.* In Fig. 3667, *E* represents the ratchet-wheel furnished with teeth shaped like those of a saw; and *A B*, the driver, is a click or paul, jointed at one end *A* to a movable arm *A C*, which has vibrating motion upon *C* as a centre. As *A C* moves to the right hand, the click *B* pushes the wheel before it through a certain space; upon the return of *A C*, the click *B* slides over the points of the teeth, and is ready again to push the

3667



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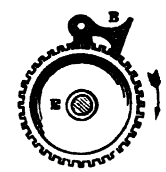

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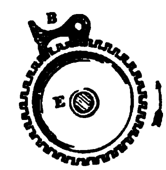

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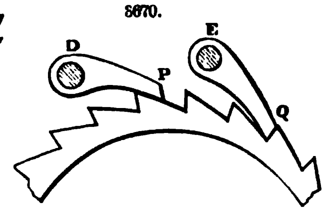

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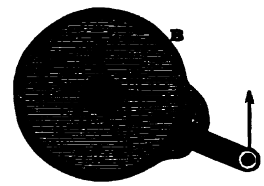


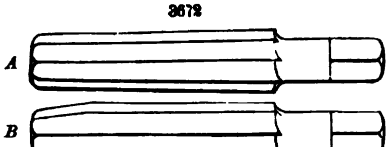
wheel through the same space as before, being in all cases pressed against the teeth by its weight or by a spring. A detent *D* prevents the wheel from receding while *B* is moving over the teeth; for it is, of course, a condition in this movement that the ratchet-wheel itself shall either tend always to fly back, or shall remain held in its place by the friction of the pieces with which it is connected. In this way the reciprocating movement of *A B* is rendered inoperative in one direction, and the circular motion results from the suppression of one-half of the reciprocating movement of the arm. The wheel *E* and the vibrating arm *A C* are often centred upon the same axis. The usual form of the teeth is that given in Fig. 3667, and the result is that the wheel can only be driven in one direction; but in machinery for cutting metals it is frequently desirable to drive the wheel indifferently in either direction; in that case the annexed construction is adopted. The ratchet-wheel has radial teeth, and the click *B* can take the two positions shown in Figs. 3668 and 3669, and can drive the wheel in opposite directions. In this case the click has a triangular piece upon its axis, any side of which can be held quite firmly by a flat stop attached to a spring; there are, therefore, three positions of rest for the click, whereof two are shown in the figures, and the third would be found when the click was thrown up in the direction of the arm produced.

In Fig. 3670 two pawls, *D P*, *E Q*, are used, which differ in length by half the space of the tooth. As the wheel advances by intervals of half a tooth, each pawl falls alternately, and the same effect is produced as if the number of teeth were doubled, and there was one pawl. In the same way three pawls might be used, each differing in length by one-third of the space of a tooth; and so the subdivision might be extended.

A mechanical equivalent for the teeth and click may be found in what is termed a *nipping lever*, constructed upon the following principle: Conceive that a loose ring, *B*, Fig. 3671, surrounds the disk *A*, and that upon a projecting part of the ring there is a short lever *D E* centred. This lever is movable about a fulcrum at *F*, near to the wheel, and terminates at one end in a concave cheek *D*, fitting the rim of the disk. On applying a force at *E* the lever will nip or bite upon the disk, and the friction set up may be enough to cause them to move together as if they were one piece.

REAMERS. Cutting tools usually employed to finish holes requiring to be very true and smooth. They may be employed in a machine or lathe, or by hand. Fig. 3672 represents reamers for hand use, *A* being a taper reamer to be introduced first, and *B* a finishing one to make the hole parallel. It is obvious that the taper one, by entering the hole a part of its length before its diameter becomes

3672



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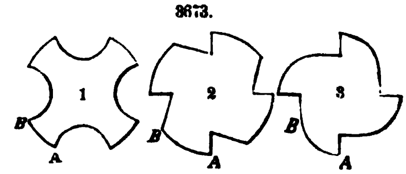

large enough to perform any cutting duty, is steadied during the operation. To steady the finishing reamer, it is usually made slightly taper at its cutting end for a length about equal to its diameter.

Reamers should be made as follows: Forge them of the very best square steel, and to within one-sixteenth of an inch of the finished size; then turn them up, taking care to properly centre-drill and square the ends, and to rough them out all over before finishing any one part, bearing in mind that the

diameter is sure to be slightly increased by the process of hardening. Then cut out the flutes in a milling machine; the number of flutes should increase with the diameter of the reamer, but a good proportion is five flutes to a reamer of an inch diameter. Let the flutes be deep and roomy, so as to allow the cuttings free egress and the oil free ingress. An odd number of flutes is better than an even one, since they render the reamer less likely to follow any variation from roundness in the hole. Nor need the flutes be the same distance apart, a slight variation tending to steady the reamer when in operation. The form of flute is not arbitrary. Fig. 3673 shows the forms usually employed, either of which will answer excellently for hand-reamers, the only difference being that No. 2 is rather more difficult to sharpen, without softening it, on an emery-wheel, while No. 1 is the most difficult to sharpen when it is softened, in consequence of the file being liable to slip out of the groove and take off the cutting edge. After the flutes are cut, the rake is given to the cutting edges by easing off or filing away the metal behind the cutting edges *A*, toward the point *B*; but this should be done by draw-filing to a very slight degree near the cutting edges, otherwise the reamer will be liable to wabble when cutting. In forms 1 and 2, the amount of the rake at the point *B* need not be more than the thickness of a piece of thin writing paper, which amount will make them work very steadily; but in No. 3, while near the cutting edge it may be very slight indeed, it must at the point *B* be considerable. Hence (save for rough work requiring an excessive cutting duty) form No. 3 is not so desirable as the others.

The best method of hardening such reamers, and in fact all others, is to heat them in molten lead, and to quench them endwise in water; because, when heated in lead, the outside will become sufficiently heated before the inside metal is red-hot; and so, when the tool is quenched, the inside or central metal will remain sufficiently soft to permit of the tool being straightened should it warp in the hardening. The straightening should be performed by slightly warming the reamer and laying it upon a block of lead with the rounded side upward; then place a rod of copper or brass in the uppermost flute, and strike the copper a quick blow with a light hammer. The use of the copper is to prevent damage to the tool by the hammer. The object of dipping the tool endwise is to prevent the reamer from warping in hardening. If great care is not taken in the hardening process, reamers and all tools having grooves or flutes in them are very apt to crack along the bottom of the flutes, which cracking is due to the unequal contraction of the metal in being rapidly cooled by quenching. Those having deep flutes, or sharp corners at the bottoms of the flutes, are the most liable to flaw in hardening, so that, in this respect, the flute shown in No. 1 is far preferable. To obviate the liability to flaw, the water in which the quenching is performed may be made sufficiently warm to be just bearable to the hand; and if it is also made a little saline, its hardening value will not have been impaired by the warming. For light work, the hand-reamer should be, if above three-fourths of an inch in diameter, tempered to a light straw color. For sizes less than that, and for heavy duty, a deep brown will prove the most serviceable, being less likely to cause the tool to break. The whole value of a reamer depends upon its being true or straight, and it is therefore necessary to exercise a great care in the resharpening, as well as in its manufacture.

Among the various devices adopted to maintain the size of a reamer, notwithstanding the wear of its cutting edge, is that of making the reamer hollow and cutting a fine slit in a portion of its length, so that by inserting a small wedge in the slit the diameter of the reamer is increased. It is to be noted, however, that the reamer is by this means altered from a round to an oval shape; but it will produce fair work if carefully used.

In Fig. 3674 is shown a square reamer, such as is used to finish the bore of rifle-barrels. Slips of wood attached to the side as shown at *A* are placed there to increase the size, as the same reamer

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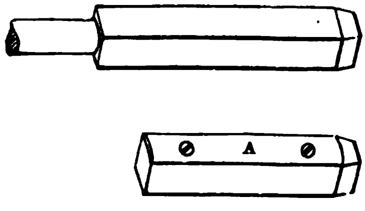

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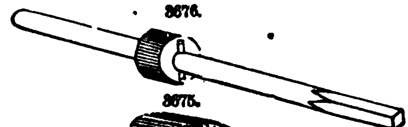

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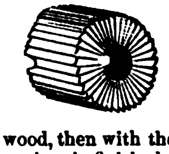

is used for a succession of cuts. First it is inserted without the wood, then with the wood, then with a piece of paper placed beneath the wood, and so on until the reaming is finished, the reamer being revolved very rapidly.

The Shell-Reamer is a cylindrical reamer having a hole bored through the centre, so that it may fit upon a mandrel and be used in the lathe. Fig. 3675 represents such a reamer, and Fig. 3676 shows

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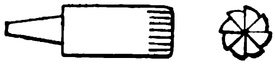


3678.

it placed upon a mandrel for use by hand. For use in the lathe, the hole is bored taper and fitted to a shank, which in turn fits into the hole of the lathe which receives the running centre; then three or four shell-reamers, having holes of the same size and taper, will fit upon one shank, thus avoiding the necessity of providing a shank for each reamer.

Rose-Bit or Reamer.—The rose-bit is nothing more than a reamer, and of this class of tool there are almost endless varieties. Fig. 3677 shows a common rose-bit, and Fig. 3678 is another form of this tool. Others are made to suit any desired shape, as globular, conical, etc.

REAPER. See AGRICULTURAL MACHINERY.

REED. See LOOMS, and ORGANS, REED.

REFRIGERATORS. Apparatus for cooling air in order to prevent decomposition in perishable materials, or to facilitate chemical processes, or to favor personal comfort during hot weather. The term "refrigerator" is most commonly applied to a box or chamber surrounded by some material which is a non-conductor of heat, and in which chamber are inclosed the ice for reducing the temperature and the substances to be preserved. It is proper to recognize two classes of refrigerating apparatus: those for cooling an air-current delivered into buildings or apartments, and the so-called refrigerators or ice-boxes which have no separate devices for producing the current.

AIR-CURRENT COOLING APPARATUS.—The simplest arrangement consists in blocks of ice placed either within or without the ducts which bring in the air. In the first case, generally preferred by inventors, the ice melts and afterward evaporates in fresh air. The cold resulting from the fusion and warming of the water produced not being more than a sixth of that due to evaporation, it follows that the amount of moisture introduced into the air is about one-seventh—nearly as much as that of evaporation alone. By causing currents of air to pass through vaults built at a depth of 6 or 8 ft. below the surface, they will be perceptibly cooled in summer. It has been proposed to place a system of pipes containing ammonia vapor in a chimney leading into the dwelling to be cooled. Refrigeration is then conducted by a process similar to that employed in the ammonia ice-machine. (See ICE-MAKING MACHINERY.) MM. Nézeraux and Garlandat have devised a cooling apparatus in which air is forced through an inclined perforated plate, over which a thin stream of water is kept flowing,

3680.

3679.

the air being cooled by contact with the water. Descriptions and illustrations of several devices for cooling air will be found in the *Scientific American*, xxxi., 23.

In the slaughter-houses of New York, fresh-killed meat intended for export is cooled by a blast from a blower which passes through a chamber packed with ice before reaching the meat receptacle. On board ocean steamers, the preserving apparatus consists of an oblong room, at one end of which is placed a chest as wide as the apartment and about 4 ft. in height. This is packed with ice, and from it extend galvanized iron pipes which connect with upright branches, and these last communicate with perforated pipes on the ceiling of the room. Around the sides of the chamber perforated iron pipes are placed. Through these, by a powerful exhaust-fan driven by the engine of the vessel, the heated air is drawn out of the room and a current of cold air is induced through the ice-box and the pipes on the ceiling. Channels for the escape of water are provided. A temperature of 34° F. has been continuously maintained. For refrigerator cars, see RAILROAD CARS.

The Tellier refrigerating apparatus consists simply in a series of flat metal plates, which are cooled by the vapor of methylated spirit, and around which the air-current passes. The refrigeration of the plates is effected by the action of a Tellier ice-machine. (See ICE-MAKING MACHINERY.) This system has been successfully used on the steamer Frigorifique, a vessel of some 900 tons, in which fresh meat has been transported from La Plata to France. It has also been adopted in large breweries, where it has maintained an air-current at a temperature of 32° F.

ICE-BOXES OR ICE-CHESTS.—The essential requirement of receptacles for food to be preserved by cold air is, that a circulation of dry fresh air shall be maintained. Moisture rapidly causes deterioration and decay. In the older forms of ice-box, the ice, wrapped in blankets, is placed in the same chamber with the food. This is objectionable, as the ice is rapidly melted by the entrance of the

enter heated air when the box is opened, and also through the drain-tube; and the condensation of moisture on the food, besides impairing its preservation, injures the flavor. Ice-chests are now more commonly constructed with the ice in a separate receptacle.

The Zero Refrigerator, devised by Mr. A. M. Lesley of New York, embodies an improved construction. Fig. 3679 shows the general arrangement. The ice-chest is located above the food-compartment, and is separated from it. A drip-pan collects all the water that is condensed on the side of the ice-chamber, and conveys it to a receptacle below, upon which a siphon-cup is fitted. The walls of the box are packed with finely-divided cork, covered with an outer coating of wood and an inner one of galvanized iron. The ice is placed upon a wooden shelf in the chest, and the water escaping below enters a reservoir, whence it may be drawn for drinking purposes.

The Allegretti Refrigerator is represented in Fig. 3680. This can be used for storing and preserving meat and vegetables in large quantities. It consists of a box of suitable size, made of matched boards, and lined with several layers of thick felting, which cover its entire inner surface. The inside of the chest is made up of two layers of pine boards closely matched and covered with galvanized iron. Between these boards and the felting a small air-space is left. The receptacle for ice is at the top of the chest, and inclines from the centre to one side, gradually narrowing until it reaches the bottom of the case. Ice is inserted through the small door at the top, in large blocks when a moderate degree of cold is required; or if a temperature below 38° is desired, the ice is crushed into small pieces, and with these the lower portion of the box is filled, the large blocks being placed on top. The floor of the case has a double bottom, under which the drip-water and cold air are allowed to circulate. It is claimed that a circulation of cold air is constantly kept up. The current from the ice-box, being directed downward, enters the chest at its bottom, and, ascending by reason of an increase of temperature gained from the articles within the chest, enters the ice-box, to be again sent down, and so on. It is claimed that a temperature below 40° F. can be maintained for any length of time.

REFRIGERATORS FOR COOLING LIQUIDS.—The simplest liquid-cooling device is the so-called "water-monkey" used in tropical climates for cooling water. It is an unbaked earthenware jar, through the sides of which some of the liquid very slowly exudes and evaporates, thus lowering the temperature of the remainder. Coolers for wort in brewing usually consist of a large shallow vat traversed by a continuous pipe, through which a stream of cold water is passed. The wort runs in one direction and the water in the other, so that the delivery end of the wort is exposed to the coolest part of the stream of water. G. H. B.

REGENERATING FURNACE. See FURNACES, IRON-MAKING PROCESSES—PUDDLING, and STEEL.
RESAWING MACHINE. See SAWS, CIRCULAR.
RETORT FURNACE. See IRON-MAKING PROCESSES—PUDDLING.
RETORTS. See GAS, ILLUMINATING, APPARATUS FOR, AMALGAMATING MACHINERY, and ASSAYING.
REVERBERATORY FURNACE. See FURNACES.
REVOLVER. See FIRE-ARMS, CONSTRUCTION OF.
RICE-HULLER. See HULLERS, COFFEE AND RICE.
RIFLE. See articles on FIRE-ARMS.

RIVETING MACHINES. For strength, etc., of riveted joints, see BOILERS, STEAM.

I. STEAM-RIVETING.—The requirements of perfect riveting are, that the metal of the rivet while hot and plastic shall be made to flow into all the irregularities of the rivet-holes in the boiler-sheets, that the surplus metal be formed into heads as large as need be, and that the pressure used to produce these results shall not be in excess of what the metal forming the boiler shall be capable of resisting. In order to test and also illustrate the relative advantages of machine- and hand-riveting, two plates were riveted together as shown in Fig. 3681, the holes of which were purposely made so as not to match perfectly.* These plates were then planed through the centre of the rivets, so as to expose a section of both the plates and rivets. From this an impression was taken with printers' ink

* From the *Railroad Gazette*.

on paper and then transferred to a wooden block, from which Fig. 3681 was made. *a* was put in by machine, and *b* by hand. The hand-rivets, it will be observed, fill up the holes very well immediately under the head formed by the hammer; but sufficient pressure could not be given to the metal—or at least it could not be transferred far enough—to affect the metal at some distance from the head. So great is this difficulty that in hand-riveting much shorter rivets must be used, because it is impossible to work effectively so large a mass of metal with hammers as with a machine. The heads of the machine rivets are therefore larger and stronger, and will hold the plates together more firmly, than the smaller hand-riveted heads.

Direct-acting steam-riveting machines give a uniform force, if the steam-pressure used be uniform; and they give such pressure as is needed, regardless in a measure of the amount of metal forming the rivet. These machines have been made on two general principles. In the English machines, a comparatively light piston of large diameter acting upon a not very large or heavy riveting ram is made to do its work by the pressure of steam alone. Machines are also built in which a very heavy piston and riveting ram are made to do the work by the combined effort of steam-pressure and momentum. The ram and piston are of wrought iron in one solid forging, and weigh when finished over one ton. With the increased weight of the riveting ram a less diameter of steam cylinder is needed. Thus, it is said that one of these machines with a steam-cylinder 31 in. in diameter, working alongside of an English machine with a steam-cylinder 36 in. in diameter, does the same kind of work from the same steam-boiler, and yet requires a shorter stroke, thus using less steam to accomplish the same result. In practice, it has been found that for locomotive boilers using $\frac{3}{4}$-inch rivets about 60 lbs. pressure per square inch does the best work.

In Fig. 3682, the frame *A* carries the bolster-die *B*. *D* is a steam-cylinder containing a piston, to the ram or rod of which the riveting die *C* is attached. The work is swung so that the heated rivet is placed in the work with the rivet-head resting in the bolster. By means of the handle *E*, steam is admitted to the cylinder *D*, causing the die *C* to strike the protruding end of the rivet, and closing it upon the work, which it will do before the rivet has lost its red heat. By another movement of the handle *E*, the ram is brought back ready to operate as before.

II. Hydraulic Riveting.—The plant required for hydraulic riveting consists of an accumulator that can be loaded so as to give any requisite pressure per square inch; a means of keeping this accumulator full by pump or otherwise; and the riveting machine proper, which may be either stationary or movable within certain limits. For boiler-seam riveting, a stationary riveting machine has its large steam-cylinder replaced by a very small hydraulic cylinder. For bridge-work construction in the shop, the pump and accumulator are placed in any convenient position, and the water under pressure is conveyed through jointed or flexible pipes to a portable riveting machine suspended from an overhead carriage. In using this portable riveting machine, the work, resting on trestles, remains stationary, and the riveter is moved along it from rivet to rivet, performing the work with great rapidity.

An adjustable accumulator and pump, in the improved form, is shown in Fig. 3683. The frame of

the machine contains the reservoir of water under compression and the reservoir of water under atmospheric pressure only. It supports a pump operated by the gearing shown, the large gear driving a crank-shaft to which is attached the connecting-rod. The movable weights shown regulate the pressure of the water in the accumulator, the pressure when all the weights are in position being 2,000 lbs. per square inch. An important feature in the arrangement of pump and accumulator is the adaptation of a relief-valve to the system. This valve is so constructed and controlled by the motion of the accumulator as to relieve the pump from work without stopping its motion when the accumulator is full, and to start it pumping into the accumulator as soon as the accumulator weight has descended a short distance.

The portable hydraulic riveting machine, to be operated by the water which the pumping device above described stores in the adjustable accumulator, is represented in Fig. 3684. In this machine the riveting dies *A B* are carried by levers of the third order, the pressure being applied at a point between the ends of the levers, as shown. The rivet is driven by the dies in the short ends of the levers, while the long ends are held together in a ball joint by a spiral spring shown at *C*. Two rods pass through guides in the cylinder *D*, and are attached to the cross-head of the plunger *E*, this attachment being adjustable. Water under pressure is admitted through a valve back of the plunger by the lever *F*. One movement of this lever admits water to the cylinder, and a reverse movement shuts off the water-supply and opens an exhaust-valve. Within the ram *E* there is a small cylinder having a piston attached at one end to the bottom of the cylinder *D;* this secondary cylinder is known as the "drawback" cylinder, and operates only when the exhaust-valve is open. The function of the "drawback" is to draw the ram *E* into the cylinder *D*, and thus to open the dies to receive the next rivet. A suspension-bar *G*, adjusted by a worm-wheel and worm, is provided to enable the machine to be presented to its work with the jaws in the most favorable position. The pipes leading to the machine are jointed, and thus made quite flexible, while the exhaust water is conveyed back to the reservoir by a rubber hose. The riveter may be suspended from any convenient crane. For girder-work it hangs from an overhead carriage made after the style of a traveling crane, and arranged to have motion in one direction of say 50 ft., and a cross-motion of say 6 ft., thus enabling the machine to cover all points in a rectangle of 50 by 6 ft.

ROAD LOCOMOTIVE. See Engines, Portable and Semi-Portable.

ROCK-DRILLS. Pointed or edged steel rods used for the perforation of rock, and caused to penetrate therein by combined percussion and rotation, or by the latter only. The rods or bits are either driven by blows of sledges and guided and rotated by hand, or are connected with the piston of a suitably arranged engine. The name "rock-drill" is now commonly applied to an apparatus which includes bit, engine, and support.

Hand-Drilling.—The curved chisel-bit, Figs. 3685 and 3686, has been proved to be the best for hand-drilling. Owing to the drill having more work to do at the circumference of the rod than at the centre, a straight-edge drill soon becomes worn more at the ends than at the middle of the edge, and it will naturally approximate to the curved edge, which, if originally adopted, therefore gives the most uniform wear. In brief, it has been found by experience that (a) Straight-edged drills blunt quickly at the corners. (b) Edges with too sharp a curve blunt first at the centre. (c) Edges with light curves are the best adapted to hard, and those with sharp curves to easier ground. (d) The proportion of the extreme width of the bit to the diameter of the drill may vary from 7 : 6 to 4 : 3. In easy rock, the shoulder of the edge need not be so great as in hard, as the ends are not subjected to so great a strain. (e) The angle of the two faces may be put at the highest for strong drills in hard rock, at say 70°, as in Fig. 3687. In hard ground, however, the drill should be rather rounded, as in Fig. 3688, to give support to the point; and in very easy material (hard earth, etc.), where a crushing rather than a cutting edge is needed, it is well to slightly blunt the edge, as in Fig. 3689.

3685. 3686.

Various devices are used for enlarging the drill-hole at the bottom. In one, the drill is provided with expanding blades, which open when the drill is turned one way, and close when it is reversed and drawn out of the hole. When closed, the plates remain in that position, and are opened automatically when the drill is struck against the bottom of the hole. As to the hammer, there have been long-standing controversies between the different races of miners with reference to the use of light hammers of from 3 to 5 lbs., or the heavy—say 9-lb. ones. The Piedmontese miners are famous for their work with the latter in 8-hour shifts. Of course, in much one-hammer drilling, especially upward work, the light hammers must be used.

As to the relative advantages of single-hand or two-hand drilling, M. Havrez (*Revue Universelle des Mines*, Liége, May and June, 1876) has determined "that, in point of economy, of time and money, one-hand drilling is from 39 per cent. in soft schists to 20 per cent. in soft sandstones cheaper than two-hand drilling. In very hard rocks, on the other hand, a saving in direct outlay of about 15 per cent. can be effected by two-hand drilling over one-hand drilling; this is especially the case with 10-hour instead of 8-hour shifts. This saving is, however, made in cost alone, as one-hand drilling gives the more rapid advance, and should be used even in the harder rocks, where speed is an especial object." In tunnel-headings, however, in America, we know that the rule is in favor of two-hand drilling in general; often, indeed, two hammers on one drill are used.

3687. 3688. 3689.

Rock-Drilling Machines.—The characteristics of a good rock-drill, according to André and Drinker, are as follows: 1. A machine rock-drill shall be simple in construction and strong in every part. 2. It shall consist of few parts, and especially of few moving parts. This principle may be carried too far, and it is even more important that every part should be easily renewed. The life of this class of machines lies in their ability to be renewed piece by piece. When a drill is thus constructed, and one is using it who is thoroughly acquainted with it, and when a sufficient number of duplicate parts are at hand, it can often be kept running month after month without dismounting,

despite breakages and wear. 3. It shall be as light in weight as it can be made consistent with the first condition. The weight, however, depends upon circumstances. If the machines are mounted on frames or carriages, and moved on wheels, we would say, make the machines *very* heavy; but if they are to be portable, and frequently dismounted in moving them, then the condition holds good. 4. It shall occupy but little space. 5. The striking part shall be of relatively great weight, and it shall strike the rock directly. 6. No other part than the piston shall be exposed to violent shocks. 7. The piston shall be capable of working with a variable length of stroke. 8. The sudden removal of the resistance shall not be liable to cause injury to any part. 9. The rotary motion of the drill shall take place automatically. 10. The feed, if automatic, shall be regulated by the advance of the piston as the cutting advances. 11. The machine shall be capable of working with a moderate degree of pressure. There are two sides to the question of pressure. If the drills do good execution at a low pressure, they must be correspondingly large and heavy, thus violating condition 3. It is decidedly questionable whether the pressure, when economical, steady work is considered, should exceed 60 lbs.; but there may of course be exceptions. Practically, the question is not one purely of high or low pressure, nor one of large or small drills, but one of economy in work and of rate of progress attained. 12. It shall be capable of being readily taken to pieces.

External gear in a rock-drill is especially to be avoided.

The 5th condition above is one of great mechanical importance. In comparing the relative merits of rock-drills, the number of strokes a minute which any one is capable of making is often insisted on as the basis of a comparison of efficiency, that one being considered the most efficient which is capable of making the greatest number of strokes. This notion is an altogether erroneous and a pernicious one, inasmuch as it tends to perpetuate and increase a somewhat serious defect. Too high a piston speed is undesirable in a rock-drill mainly for two reasons: First, the resistance to be overcome is great. The operation of boring consists in fracturing the rock by a succession of heavy blows, and it is evident that the heavier the blow, within the limits of the endurance of the tool, the greater will be the effect. Theoretically, the stroke should be very short, so as to divide the work of the motor into a very great number of blows, and so pick the rock to pieces. A blow hard enough to break and smash the steel may indent the rock; but divide this blow into many, and we drill a hole. But the stroke may be too short. There must be a certain clearance; and the shorter the stroke, the greater the percentage of loss of steam in filling the cylinder. Also, the drill must churn up the débris in the hole so that the water will wash it out; but if the stroke is too short, it will only clog. Hence we have a paradox—to drill hard rock requires a harder blow than to drill soft rock, but to clear the hole requires a longer stroke; so that a drill with 3½-inch stroke drills hard rock best, but for soft rock it should be 6 or 7 inches. A long, heavy stroke on hard rock jars the machine too much. To obtain a heavy blow, there must be a large moving mass. But an augmentation of the mass is, other things being equal, incompatible with an increase of velocity. Hence it becomes desirable, as far as the 3d condition will allow, to renounce velocity in favor of mass; i. e., as much as practicable of the weight of the machine should be concentrated in the piston and piston-rod. With such a disposition of the parts, the work of a drill must necessarily be more effective. Second, when the moving mass is light and the velocity high, not only is the great resultant vibration absorbent of force, but very destructive to the joints and conducive to fracture in the moving parts; and, moreover, the inevitable wear and tear are thereby immensely increased, so that the tendency to derangement is greatly augmented by the adoption of high velocities.

As to the 6th condition, a source of accidental shot of extremely violent and destructive character lies in the necessity for a variable piston-stroke. The provision for this variation of stroke allows the piston, under certain circumstances, to come into contact with the cylinder-cover. When, as is sometimes the case, the valve-gear acts independently of the piston, the liability to this accident is greatly increased and becomes a very serious defect.

In the design and construction of every machine-drill, the tendency of the piston to exceed the proper limits of its stroke should be constantly borne in mind, and means should be employed both to check that tendency and to lessen its effects. A rock-drill operates upon the rock by striking a blow, and it is essential that the blow should be struck with the full force of the stroke. When the rock is very hard, several blows may be struck in succession without either penetrating the rock or breaking away any part of it. A subsequent blow acting on the parts weakened by those already received causes fracture, and, the fractured portion instantly becoming detached, the hole is suddenly deepened. The piston will therefore have to advance farther at the next following stroke. Moreover, rocks vary suddenly and greatly in hardness, and often contain cavities, besides which they are always more or less traversed by joints. The sticking of the drill in the hole from any cause is another source of trouble. It often causes the piston to strike the back head, for steam (or compressed air) packs in front of the piston, and as soon as the drill is freed, the piston is forced back with unusual violence and strikes the rear end. If all the circumstances are borne in mind, a little reflection will suffice to show that, even assuming perfect feeding to be possible, a rock-drill could not operate with an invariable piston-stroke, and that the piston must, in the matter of length of stroke, accommodate itself to the requirements of the moment. But as no automatic feed-motion has been devised sufficiently accurate in its action to satisfy the demands of practice, and as hand-feeding is in its nature more imperfect still (though it is probably the better system), the necessity becomes obvious, not merely for a possible variation in the length of the stroke, but for a variation between somewhat wide limits. This renders it impossible to connect the piston in an invariable manner with the valve-gear. Hence recourse has been had to tappet movements to actuate the valve, and in some instances the valve-motion has been made wholly independent of the piston. (The principle is the same as in the direct-action steam-pumps, where tappets are almost always used.)

The 8th condition is practically a part of the 6th. Rocks often contain cavities, and when a drill enters one of these, the resistance to the tool is suddenly removed, and this causes the piston to give

its extreme length of stroke, and, in consequence of a tendency to exceed the limit, it often strikes against the cylinder-cover. A provision against its occurrence consists in allowing ample clearance space at the lower end of the cylinder, or of inserting an elastic buffer.

Now, assuming that practice has decided, as to the rotary motion of the drill, that it should be automatic, we have nevertheless seen that there are strong reasons, on the other hand, in favor of a hand-feed over an automatic. Should, however, the feed of a drill be automatic, the 10th condition, that, "if automatic, it shall be regulated by the advance of the piston at each stroke," is one of essential importance.

In any mechanism in which a regular progressive action is communicated to the tool, no account is taken of the irregular manner of producing fracture in the rock, of variations in hardness, of the occurrence of joints and cavities, or of the comparative sharpness or bluntness of the cutting edge of the tool. A certain velocity of progression having been assumed, the inevitable consequence is, either that the tool is not kept properly up to its work, or is pressed forward too rapidly. In both cases, the result is a serious loss of effective work, often accompanied with no less serious delays. With these facts in view, the practical mind will at once note the importance of observing this condition.

As to the 11th condition, which requires that the machine shall be capable of working with a moderate degree of pressure, it is one that must tend greatly to promote the successful employment of rock-drills actuated by compressed air.

The general plan of holding the drill-shank is by means of friction induced by bolts, the latter not being forced directly against the shank. The Z-bit is considered the best form theoretically for cutting, for the greater part of the cutting edge is around the circumference of the hole, where most of the cutting is done. But the greater liability to break, and the greater difficulty of repairing and sharpening, has made the X-shape more acceptable.

3690.

Hand-Drilling Machines.—In Figs. 3690 and 3691 are illustrated two forms of hand-drilling machines. In that represented in Fig. 3690, when the crank is turned the wheel *A* is rotated, and by the cam on this the rod *B* both lifts and turns the drill *D*, against the action of the spiral spring. The elasticity of the latter supplies the power for causing the drill forcibly to strike the rock. The Victor drill, shown in Fig. 3691, is one of the most efficient of its class. In this, by rotating the handles, cams are caused to lift the drill against the heavy springs shown. An ingenious self-feeding attachment is provided. This machine will cut in average rock from 3 to 6 ft. per hour.

3691.

Power-Drilling Machines.—The Rand Drill.—The essential principles embodied in the construction of this drill will be understood from the sectional view, Fig. 3692. The lever for operating the valve is placed in a recess between a double-headed piston, and is struck at the ends as the piston reciprocates, and the arm of the lever drives the valve. The valve is made of steel, and so constructed that it moves in the same direction as the piston in opening the ports, without the use of an eccentric rod. The piston-rod enters the piston on a taper, and is keyed into place. The rotation-bar is nearly triangular in cross-section, and is made very strong. The ratchet-wheel for rotation is large, and the teeth are strong.

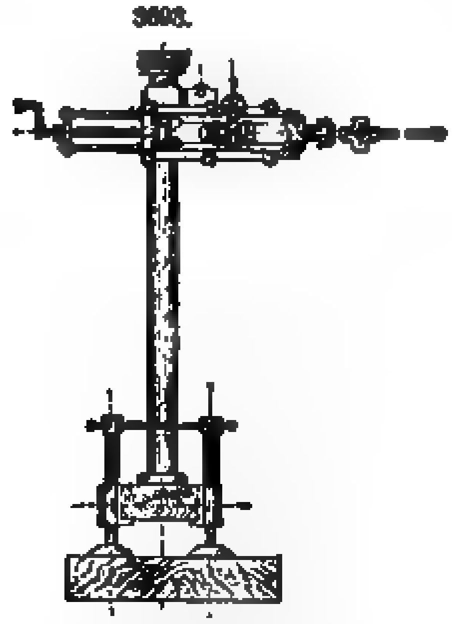
Fig. 3693 represents this drill supported on an ingeniously constructed column for use in headings. It will be noted that the column may be adjusted to any height by the screws which pass through its base. Fig. 3694 shows the arrangement of the drill for gadding, capping, and raising blocks. It

3694.

can also be used as a coal-cutting machine. Fig. 3695 exhibits the drill mounted for doing quarry work. A straight line of holes 8 ft. in length can be put down without moving the machine, all the holes having the same direction.

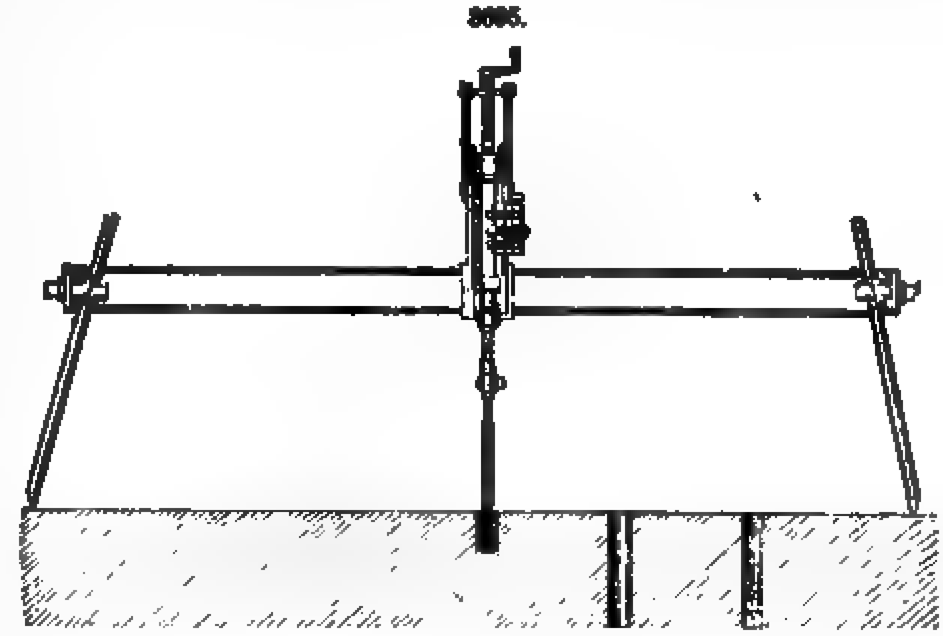
The Rand air-compressor, used to supply air under pressure to the drill above described, is illustrated in a full-page plate. (See AIR-COMPRESSORS.) The machine here represented is that constructed for use in the Calumet and Hecla mine. Its principal features are the double-acting cylinders, 28 in. in diameter by 48 in. stroke, and the method of absorbing the heat due to compression by surrounding the sides and end of the cylinders and filling the interior of the piston with cold water. It will be noted that there are two air-cylinders placed side by side, with cranks set at quarter angles, driven by cut gears from the main shaft which operates the mine-pumps and hoisting drums. This shaft is driven by Leavitt compound engines of about 1,500 horse-power. Each compressing cylinder has three concentric shells, the inner one of which is of brass, and the others are of cast iron. Between the inner and the middle shell a constant circulation of water is maintained. This water passes through the piston, and thus serves both as a means of cooling and a lubricant. Brass is used for the interior of the shell on account of its superior conducting qualities. Relief-valves properly weighted are provided, by means of which the engine is relieved of duty when the pressure in the receiver exceeds the desired number of pounds per square inch. A number of small inlet- and discharge-valves of steel are placed in the heads of the cylinders, the object of using many small valves being to lessen the shock while seating.

3693.



Drilling under Water.—There are two methods in use for drilling rock for blasting under water: one by shaft-sinking and tunneling, as practised at Blossom Rock and at Hell Gate (see BLASTING); and the other by drilling from the surface. The last-mentioned operation may be accomplished either by building a platform over the rock to be perforated, and erecting the drills thereon, or by means of a scow on which the drills are placed. The older method of constructing drill-scows is to make a "well" through the bottom, through which a drop-drill is caused to work. This drill is guided by holes in a heavy iron bell, which is let down from the scow and adjusted over the rock to be bored. A description of this system will be found in the *Scientific American*, xli., 31.

3695.



An improved construction of drill-scow is represented in Fig. 3696. The drills, instead of passing down through the vessel, are placed at the ends, and suitable mechanism is provided for raising and lowering them in a vertical line. The bits extend down through tubes, which are attached to mov-

3696.

THE RAND DRILL-SCOW.

able carriages running on transverse ways. The scow, after being floated over the rock to be bored, is lifted bodily out of water if need be, by spuds which are forced down against the rock, thus forming an immovable platform. Fig. 3696 shows the scow used in the improvement of the St. Lawrence River near the mouth of the Lachine Canal. Four Rand drills of 5 in. diameter were employed. The maximum cutting was 9 ft. of rock under a depth of 9 ft. of water, the design being to make a clear channel 18 ft. in depth. During 1878 and 1879 the scow worked on an average six months per year, and the removal of about 45,000 yards of rock was effected.

Report of Experiments with the Rand Rock-Drill made by Park Benjamin's Scientific Expert Office, New York, March, 1879. Experiments conducted by Richard H. Buel, C. E.

The following experiments were made in order to measure the speed of the drill and consumption of air at different temperatures. A counter was attached, receiving its motion from a lever actuated by a cam-shaped projection on a piston-rod constructed for the purpose—the effect of the attachment being to make the reading of the counter increase one unit for each successive pair of strokes (advance and return of the drill). A collar was secured to a groove in the piston-rod, and a rod attached to this collar gave a rocking motion to a lever pivoted to a standard on the front cylinder-head of the drill. This constituted the motion for the indicator. Pipes were connected to each end of the cylinder, and united at the middle by a three-way cock to which the indicator was attached. A piece of 4-inch pipe was connected to the exhaust, and the discharge end of this pipe was accurately finished on the interior for a distance of about a foot. The pipe was several feet in length, and a water-gauge was connected to it close to the discharge end. Thermometers were attached as follows: one in the delivery-pipe of the air-compressor, at the point of its entry into the reservoir; one in the valve-chest of the drill; and one in the exhaust-pipe, within a few inches of its connection with the drill. The pressure-pipe connecting the drill with the air-reservoir was short and free from abrupt bends.

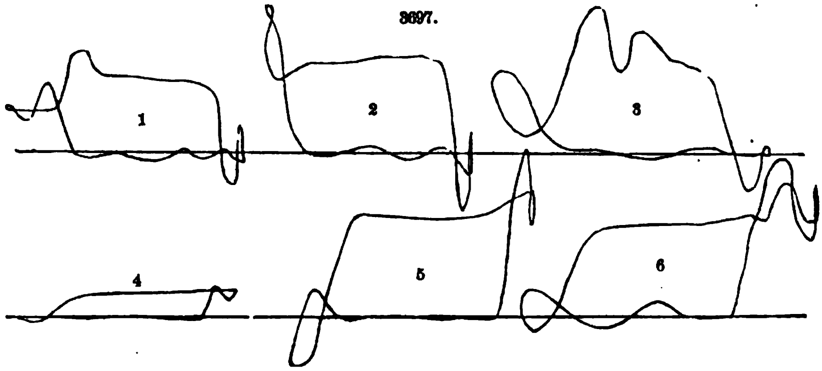
In making the experiments, when the drill was permitted to strike, the blows were received by a mass of iron, a blunt-headed rod being used in place of the ordinary pointed drill. By this means the stroke of the drill was maintained practically constant. The following are the principal dimensions of the drill, as obtained by measurement, the volume of parts being measured by filling them with water:

Diameter of piston	3.125 in.
" of rod	1.625 in.
Area of feed-screw at back end	2.0046 sq. in.
Mean piston area	5.6307 sq. in.
Maximum stroke of piston	6.75 in.
Average stroke during experiments	6.00 in.
Port clearance, front end of cylinder	7.0996 cub. in
" " back end of cylinder	6.682 cub. in.
Diameter of exhaust-pipe at point of discharge	4.07 in.

Indicator diagrams were taken from the drill-cylinder at speeds varying from 111 to 298 double strokes per minute, and at pressures of from 12.5 to 26.5 lbs. per square inch above the atmosphere. Before taking diagrams the piston of the drill was blocked in position, and subjected to a high pressure, and was found to be practically tight. The pressure-gauge was also tested by the indicator (the springs of which had previously been found to be correct), and all records of gauge-pressures given hereafter are corrected readings. In all diagrams taken, the pencil was allowed to pass over the paper a number of times, but without making any material change in the form.

Representative diagrams are given in Fig. 3697. Diagrams 1, 2, and 3 are from the front end of the cylinder, or were taken on the return stroke; and diagrams 4, 5, and 6 are from the back end,

3697.



representing the striking stroke. Diagrams 1 and 4 were taken with the drill run back in the frame so as not to strike, and in all the remaining diagrams the drill was allowed to strike, the length of stroke being maintained at 6 in. as nearly as possible. When not striking, the speed of the drill was controlled by the throttle-valve, but for the other runs the throttle-valve was kept wide open and

a constant pressure was maintained in the reservoir. The principal results from the diagrams are contained in the accompanying table:

Table showing Data from Indicator Diagrams of Rand Rock-Drill.

NUMBER OF DIAGRAM	1	2	3	4	5	6
Pressure in reservoir above atmosphere	....	12.5	26.5	....	12.5	26.5
Number of double strokes per minute	185	200	298	185	208	298
Scale of indicator springs	1/12	1/12	1/24	1/32	1/12	1/24
Mean effective pressure in lbs. per sq. in	5.78	8.54	18.6	6.66	8	11.5
Ratio of pressure during period of admission in cylinder to pressure in reservoir	....	.95	.89	....	.98	.89
Fraction of stroke completed to exhaust	.87	.85	.76	.72	.78	.76
Fraction of stroke completed to cushion	.71	.81	.78	.84	.88	.70

Indicated horse-power computed from each pair of corresponding diagrams—Nos. 1 and 4, 0.143; Nos. 2 and 5, 0.285; Nos. 3 and 6, 0.638.

Direct measurements were also made of the amounts of air used by the drill at different speeds and pressures, by placing an anemometer at the end of the exhaust-pipe, one observer taking the readings of the anemometer while another made simultaneous records of the counter. The pressure was increased in the successive runs, being maintained constant in the reservoir during each of the several runs until it was no longer possible to hold a steady pressure in the reservoir. Several readings of counter and anemometer were taken in each run; the water-gauge in the exhaust-pipe gave no sensible indication, showing that the air was discharged at atmospheric pressure. The anemometer used in these experiments had previously been tested up to a velocity of between 500 and 600 feet per minute, and its correction as thus determined has been applied to all the observed velocities. The air passing the anemometer was at exhaust temperature and atmospheric pressure, and this has been reduced to reservoir temperature and pressure. Similarly the air saved by cushion has been correspondingly reduced, and in the accompanying table the results of these reductions are presented:

Table showing Experiments on Speed of Rand Rock-Drill and Volume of Air used at Different Pressures.

NUMBER OF EXPERIMENT	1	2	3	4	5	6	7	8	9	10
Pressure in reservoir above atmosphere	15	20	25	30	35	40	45	50	55	58
Double strokes per minute	225	250	280	309	338	348	395	415	429	452
Temperature (Fah. degrees), reservoir	75	82	85	90	100	105	130	135	150	160
" " " valve-chest	70	70	70	70	71	75	80	80	80	80
" " " exhaust	57	52	48	46	44	42	43	44	44	44
Velocity of air in exhaust-pipe	246	358	510	724	850	1,012	1,250	1,484	1,690	1,738
Cub. ft. of air exhausted per min. at exhaust temperature and atmospheric pressure	22.8	32.8	46.1	65.4	76.8	91.4	112.9	134.1	152.7	161.5
Probable equivalent of air exhausted at reservoir pressure and temperature	10.4	12.2	14.5	17.9	18.7	19.2	20.0	20.8	21.9	22.2
Cub. ft. of air used per minute, calculated from total piston displacements	11.1	12.8	13.9	15.8	16.5	17.2	19.6	20.5	21.2	22.4

U. S. Government Tests of Drills at Hell Gate.—A series of tests of drills were made during 1878 and 1879 by Capt. James Mercur, U. S. Engineer at Flood Rock, Hell Gate, N. Y. The drills used were the Burleigh, Rand, and Ingersoll. All had 3-inch cylinders, and were operated with a 1¼-inch octagon steel upset to a 2-inch bit, drilling a hole somewhat larger than 2 in. in diameter at the start and somewhat smaller at the end. The holes averaged 4 ft. in depth, and the character of the rock varied from the hardest to the softest varieties of gneiss. The following data are the averages for six months (March 1st to September 1st, 1879), the work being carried on continuously in three shifts of eight hours each, no deduction being made for time lost by breakages and moving drills. In the average by hours only the actual drilling time is counted. The air-pressure was kept at 60 lbs. per square inch:

Number of shifts worked	1,282
Average per shift	36.8 feet.
Number of hours worked	9,230.08
Actual drilling	47,132.11 feet.
Average per hour	5.11 "

The Burleigh Rock-Drill.—The main elements of this drill are the cage, the cylinder, and the piston. The cage is merely a trough, with ways on either side, in which the cylinder, by means of a feed-screw and an automatic feed-lever, is moved forward as the drill cuts away the rock. The piston moves back and forth in the cylinder, propelled and operated either by steam or compressed air, like the piston of an ordinary steam-engine. The drill-point is attached to the end of the piston, which is a solid bar of steel. The piston is rotated, as it moves back and forth, by ingenious and simple mechanism. The forward motion of the cylinder in the trough is regulated by an automatic feed as the rock is cut away, the advance being more or less rapid, as by the variation in the nature of the rock the cutting is fast or slow. It will thus be seen that the drill-point and solid steel piston alone receive the shock of the blow; and it also should be stated that the piston-rod, arranged with a double annular cam and spiral grooves, in its movements performs three important functions: 1. The movement of the valve admitting the steam or compressed air to the

cylinder. 2. By the operation of the annular cam acting upon the feeding device, the cylinder is moved forward (as the rock is penetrated) in the cage or slide. 3. By the spiral grooves and a spline in the ratchet, the piston-bar is automatically rotated, a partial revolution taking place at each upward movement of the piston, the ratchet remaining perfectly stationary while the rotating movement occurs, and moving only as the piston again descends. When the cylinder has been fed forward the entire length of the feed-screw, it may be run back, and a longer drill-point inserted in the end of the piston. By an ingenious peculiarity in the form of the cutting edge of the drill-point, perfectly round holes are insured, thus giving a greater area to the whole, and a larger percentage of the powder near its bottom.

The drilling machine is attached to a clamp by means of a circular plate, with a beveled edge cast upon the bottom of the cage near its centre. This plate fits a corresponding cavity in one side of the clamp, and is held there firmly in any required position by the tightening of screws. The clamp is clasped about a bar of iron, to which it may be tightly held by screws.

By the motions—upon one plane, of the plate in its cavity, and upon another, at a right angle to the first, of the clamp upon the bar, and the sliding endwise of the clamp upon the bar—it will be seen at once that any position and direction of the drill is attainable. It only remains to attach the bar, of any reasonable length, to a convenient carriage or frame, and the machinery is ready for operation.

These machines are applicable to all kinds of rock-work, whether mining, quarrying, cutting, tunneling, or submarine drilling. They combine simplicity, strength, lightness, and compactness, are easily handled, and require but few repairs. With them, it is stated, holes may be drilled from three-fourths of an inch to 5 in. diameter, and to a depth not exceeding 30 to 35 ft., at the rate of from 2 to 10 in. per minute, according to the nature of the rock. They are driven by either steam or compressed air as a motor, and, at a pressure of 50 lbs. to the inch, work at 200 to 300 blows per minute, according to the size of the machine.

The details of construction will be understood from the following references to the sectional view, Fig. 3698: *C'* is the cage; *C Y*, the cylinder; *Y*, the yoke; *F S*, the feed-screw; *B C*, the back cap; *R*, the rubber buffer; *B H*, the back head; *C*, the chuck; *S*, the stuffer; *F H*, the front head; *P''*, the valve-rod packing; *P*, the piston; *P'*, the piston-packing; *T*, the tappets; *S C*, the steam-chest; *V R*, the valve-rod; *V*, the valve; and *V S*, the valve-starter.

3698.

Fig. 3699 represents a stoping-drill mounted on a column, with a claw-foot and a jack-screw at top for securing the same in upright position. This is peculiarly adapted to small tunnels, adits, and stopes, from $4\frac{1}{2} \times 6$ ft. to 6×6 ft., or even larger drifts. It is largely used in the mines of California and Nevada.

Fig. 3700 represents a carriage for mounting four drills upon two bars, the lower of which may be raised and lowered by means of chains, pulleys, and a windlass. The apparatus is constructed with an open space of from 4 to 16 ft. in the clear, between the two sides, so that it may be run in as soon after a blast as the track can be cleared by throwing the rock into the centre. Drilling can thus be resumed with but little loss of time, and the removal of the rock proceed simultaneously by means of small cars running upon a narrow-gauge track laid inside the carriage-track. It has jack-screws to raise it from the wheels during the drilling, and is held in place, like the smaller carriage, by screws running out from the ends of the upper bar, or up from the frame to the roof of the tunnel. It is constructed of wood and iron, and runs upon iron car-wheels. A tunnel 8 ft. in height, and from 10 to 16 ft. wide, can be constructed by the use of this carriage; and, by means of an enlargement carriage, the size can be increased in height and width sufficiently for any purpose for which a tunnel will ever be needed. For running a double-track railroad tunnel, two carriages of this form are commonly used side by side. This style of carriage is used in the great Sutro Tunnel of Nevada.

The following data exhibit the capacity of this drill at the Hoosac Tunnel, from report of Mr. W. Shanly, contractor:

Memorandum of Drilling in Heading from Central Shaft, August 11th to 27th—10 Shifts.—Total time occupied in drilling, 38 hours 40 minutes = 2,320 minutes. Total number of holes drilled, 120. Total number of inches drilled, 16,948. Average depth of holes, 11 ft. 8 in. Average number of drills used each shift, 6. Average number of inches drilled to the minute, $7\frac{30}{100}$. Average number performed by each machine each minute, $1\frac{22}{100}$. In doing above work, drill-points were changed 694

3699.

times. Average number of inches drilled by each point, say, 24$\frac{1}{2}$. The maximum shifts-work, including above, was on August 17th, 6.30 A. M. to 9 A. M., 2$\frac{1}{2}$ hours. Number of holes drilled, 12. Number of inches drilled, 1,728. Number of minutes occupied in drilling, 150. Average of inches drilled per minute, 11$\frac{1}{2}$. Number of machines used, 6. Average inches per minute each drill, 1$\frac{81}{100}$. Drill-points changed, 61 times. Average inches to each point, 28$\frac{1}{2}$.

The above work represents the centre cuts taken out between the dates given. The balance of the 17 days were occupied in squaring the cuts. The advance made in heading, August 11th to 27th inclusive, was 107 ft.

The following statement from the Sutro Tunnel Company, of Nevada, is official:

Sutro Tunnel Co., June 30, 1875.—Commenced in October, 1869, run 4 years by hand, size 4$\frac{1}{2}$ × 6—5,200 ft. Thirteen months since the drills were introduced and the size of tunnel increased to 8 × 12. Run in 13 months, 4,278 ft. Average weekly progress, 70 ft. Expense by hand-labor, which included pumping, monthly, $34,000 to $50,000. Expense by machine (pumping abandoned), monthly, $14,000 to $16,000.

The Diamond Drill.—The general principle of boring with the diamond drill is the same, the different machines, by comparatively slight changes, being applicable to any kind of rock-drilling. For deep boring, for wells, or prospecting mineral lands, a machine is used with a double oscillating-cylinder engine, mounted on an upright or horizontal tubular boiler, Fig. 3701. The capacity of the engine varies according to the depth and size of hole requiring to be bored. These machines have a screw-shaft made of heavy hydraulic tubing, from 5 to 7 ft. in length, with a deep screw cut on the outside. The shaft also carries a spline by which it is feathered to the lower sleeve-gear. This gear is double, and connects by its upper teeth with a beveled driving-gear, and by its lower teeth with a release gear, which is a frictional gear, and is fitted to the lower end of the feed-shaft, to the top of which a gear is feathered, fitting to the upper gear on the screw-shaft, which has one or more teeth less than the upper gear on the feed-shaft, whereby a differential feed is produced. This frictional gear is attached to the bottom of the feed-shaft by a friction-nut, thus producing a combined differential and frictional feed. The drill-rod, made of heavy lap-weld tubing, passes through the screw-shaft, and is held firm by a chuck at the bottom of the screw-shaft. To the

3701.

3700.

lower end of this tubular boring-rod the bit is screwed, and to the upper end a water-swivel, to which connection is made with the steam-pump, as shown in the illustration. By means of this pump a constant stream of water is forced down through the hollow drill rod, thereby keeping the bit cool and the hole bored clear of sediment, which is forced by the water-pressure up the outside of the rods to the surface. The hollow bit is a steel thimble, having three rows of diamonds (bort or carbon) imbedded therein, so that the edges of those in one row project from its face, while the edges of those in the other two rows project from the outer and inner periphery respectively (*A*, Fig. 3702). The

3704.

diamonds of the first-mentioned row cut the path of the drill in its forward progress, while those upon the outer and inner periphery of the tool enlarge the cavity around the same, and admit the free ingress and egress of the water, as above described.

The screw-shaft, being rotated and fed forward, rotates the drill-rod and bit, and, as the bit passes into the rock, cutting an annular channel, that portion of the stone encircled by this channel is of course undisturbed; the core-barrel, passing down over it, preserves it intact until the rods are withdrawn, when the solid cylinder thus formed is brought up with them, the core-lifter breaking it at the bottom of the hole and securely wedging and holding it in the core-barrel. Where a core is not required, the perforated boring-head (*B*) can be used, the detritus being washed out by the water inserted through the drill-rod, the same as when boring with the hollow bit. In order to run the screw-shaft back after it has been fed forward its full length, it is only necessary to release the chuck and to loosen the nut on the frictional gear, which allows the gear to run loose; then the screw-shaft will run up with the same motion which carried it down, but with a velocity 60 times greater; that is, the speed with which the screw-shaft feeds up is to the speed with which it fed the drill down as 60 to 1, the revolving velocity in both cases being the same. By tightening up the chuck and nut on the frictional gear, the drill is ready for another run The drill-rods may be extended to any desired length by simply adding fresh pieces of tubing, the successive lengths being quickly coupled together by an inside shoulder-nipple coupling, made of the best of forged iron, and having a hole bored through the centre to admit passage of the water. In order to withdraw the drill-rods, they are uncoupled below the chuck, and the swivel-head, which is hinged, unbolted and swung back, thereby moving the screw-shaft to one side, and affording a clearance for the rods to be raised by the hoisting gear on the machine, without moving the drill. By the erection of a derrick of sufficient height, it will be necessary to break joints only once in every 40 or 50 ft.

One of the most thorough records we have of the cost of work by the diamond drill is in a paper read before the American Institute of Mining Engineers, June, 1876, by Mr. Lewis A. Riley, Chief Engineer of the Locust Mountain Coal Company.* The results given were obtained, during the years 1875–'76, by means of two drilling machines belonging to the Lehigh Valley Coal Company, and operating on their coal-land in the Mahanoy, Lehigh, and Wyoming regions. The majority of the holes were put down for the purpose of proving the lower veins of the coal-series; they had to encounter the harder rocks of the coal-formation, much of the distance being through the lower conglomerates, going in some cases through the coarse egg conglomerate, the foundation of the coal-deposit, and to the greenstone and red shale which underlie it. The boring was done with a No. 2 drill, of an improved design, of large size, with oscillating engine of 15 horse-power. During one year it drilled 9 holes, of a total length of 4,562 ft., without being once repaired, or incurring any cost outside of the ordinary running expenses. The deepest hole bored was 900.5 ft. long. The total length of holes bored was 9,901 ft.; the average progress per day, 18.9 ft. The average cost per foot was $2.22, viz.: for labor, $1 15; for diamonds, 66 cts.; for supplies, repairs, etc., 41 cts.

The Ingersoll Drill is represented in Fig. 3703, which is a longitudinal section: 1 being the feed; 2, exhaust; 3, valve; 4, ports; 5, valve stems; 6, tappet; 7, piston; 8, an 8-inch thread-screw fitting into the piston, which thereby receives the rotary motion necessary; 9, tappet, from which the motion is communicated by the bar, 10, to a pawl and ratchet movement acting on the feed-screw 11.

The McKean Drill, Fig. 3704.—The turning movement of this drill is effected by means of a cylindrical enlargement formed on the piston-rod. Spiral grooves are cut in the face of this enlargement, which is constantly in gear with a spirally grooved cylinder placed parallel to the piston-rod, and capable of revolving. On the return stroke of the piston the cylinder is maintained by a ratchet motion in a fixed position, while the piston-rod, sliding upward in gear with the cylinder, is necessarily turned on its axis to a degree proportionate to the twist of the spiral and the length of the return stroke; thus the new angular position of the jumper is secured. During the forward stroke the spiral cylinder does not influence the piston-rod, which moves straight forward, and, on the contrary, turns the cylinder on its own axis. On the next back stroke the piston-rod is again seized by the spiral cylinder, which is now brought up with its ratchet detent, and is turned round, as before, preparatory to making the next forward stroke. The compressed air is supplied to or

* *Engineering and Mining Journal*, vol. xxii., No. 15.

exhausted from the cylinder through a hollow oscillating cylindrical valve. This is moved by tappets, the action of which is also utilized for effecting the feed, which, by a combination of ratchet-wheel and screw, may be minutely graduated.

At a test of this machine at the St. Gothard tunnel, in 1874, it was found to bore 1.4 inch per minute.

The Ferroux Drill, Fig. 3705.—This consists of two cylinders, set end to end, and fitted with pistons, rods, and a frame in the machine for tunnels, while in the machine for mines and shaft-sinking, etc., the cylinders are set side by side one above the other. The one is called the propelling cylinder, and the other the boring cylinder; the propeller feeds the borer up to its work. The compressed air is introduced into the machine through a cock, and enters the first cylinder *L*, which is the propeller cylinder; in this is placed the piston *M*, fixed on a tubular rod *N*, the other end of which is securely fixed to the boring-cylinder *T*, in which reciprocate the piston *O* and the boring-rod *B*. The compressed air entering at *I* produces three actions: First, it presses before it, in a continuous manner, the boring-cylinder toward the rock to be perforated; and when the borer has pierced the rock to a depth equal to the "pitch" of a tooth respectively, in a pair of racks fitted to the upper part of *A A*, the boring-rod *B*, by means of a collar *C* affixed on it, now raises a forked lever *D*, which is provided with a pair of projections acting as pawls on the racks fixed on *A A*, and the borer is urged forward a distance equal to one notch of the rack. The boring-cylinder is thus, as it were, consolidated with the action of the borer, but it is necessary that it should be also in a sense opposed to it; it is therefore provided with two small cylinders *X X*, arranged horizontally, as at *C D;* in each of these works a piston, so formed on its outer side as to act as a pawl, which engages in the teeth of the rack formed on the inner face of each of the frame-bars *A A*. It will be seen that the action of these pawls is the reverse of those regulating the forward movement of the propeller, and they operate to prevent any greater degree of recoil on the part of the borer upon the propeller than the pitch of a tooth in the racks; so that, while such pitch admits of an elastic cushion to soften the recoil action and prevent fracture, at the same time the play is too limited to vitiate the boring action. As the pistons in *X X* are subject to the action of the compressed air, they are thus kept forced into the ratchet-teeth, while their oblique leading faces prevent them from obstructing the feed-movement.

The second action of the compressed air is to operate through the hollow rod *N*, and supply power to actuate the boring-piston *O* in the cylinder *T*. The air enters the valve-box *P*, and is alternately admitted before and behind the piston *O* by the slide-valve *Q* in the box *P*.

The third action of the compressed air is to actuate the air-engine at the rear of the propeller-cylinder *L*. This engine is constituted of a cylinder within, which works a piston with a trunk-rod *R*, over which is a crank and shaft united to the piston by a connecting-rod. The crank is a slotted one, having on the one side an eccentric to shift the slide-valve for its own cylinder, and at the other side a socket-sleeve into which the end of the long shaft *S* is fixed. Beyond the bracket supporting this end of the shaft is a fly-wheel of exceedingly small diameter, so as to economize room for the headings, but wide enough to secure weight sufficient for

steady working. The shaft S is prolonged and supported in another bracket at the boring-bar end of the machine, and beyond it is an eccentric which actuates a reciprocating ratchet which engages in the ratchet-wheel V on the boring-bar, giving it an intermitting rotary movement of one tooth-pitch at each blow dealt by the tool upon the rock. To withdraw the tool from its work, it is only necessary to close the cock I and open that at J, when the air which pushed the machine forward escapes, and the compressed air passing through J goes along the pipe $K K$ to the front side of the piston M and forces it back, which withdraws the tool and closes up the machine like a telescope. A socket Y serves to fix it to any supporting machine.

The following test of the Ferroux drill was made at the St. Gothard tunnel, the experiment being to bore 320 ft. of holes with 6 machines: Total time of boring and of changing the drills and the machines when worn or disabled, 15.9 hours; total length per minute with 6 machines, 4.2 inches; for each machine .7 inch; number of fresh drills used, 621; machines disabled or removed for repair, 3.5; rock, granitic gneiss.*

The Dubois and François Drill, Fig. 3706.—This machine consists of four parts: a gun-metal cylinder, a distribution-valve, a piston carrying the drill-holders, and a frame formed of two bearers. The compressed air employed to work it enters the cylinder A, closed at the ends by the pistons B C, which are connected together by the frame carrying the valve D. The diameter of the piston C being greater than that of B, the air-pressure forces the whole of this combination toward the right, the port is opened, and the compressed air enters the cylinder E, and drives the piston and drill attached to it against the face of the rock. But during the operation the compressed air in the chamber A passes by the ports i i behind the piston C, and reverses the motion; the combination B C D is then moved to the left; another port is opened, and the air-pressure is exerted behind the piston F, while the air which was previously used to drive the piston forward escapes into the atmosphere. The piston then returns, but before arriving at the end of its stroke, and by means of a swelling on the piston-rod, the finger H is lifted. The compressed air behind the piston C then escapes into the atmosphere, and the apparatus is thus in a condition to repeat the operation first described of delivering a second blow upon the face of the rock. By this arrangement it will be seen that, while the compressed air acts instantaneously on the piston in making a stroke, it acts only progressively in returning; it will also be seen that, by changing the diameter of the small opening i, the speed of the machine will be modified.

The rotation of the drill is effected by means of the two pistons, which are subjected alternately to the compressed air, and transmit their motion to a ratchet and other mechanism. The forward motion of the cylinder, as the depth of the hole in the rock increases, is effected by turning the handle and the screw Y.

At the St. Gothard works, six of these drills are mounted on a carriage-frame, as illustrated in Fig. 3707.

Six machines of the Dubois and François type, at the St. Gothard tunnel, in competition with Ferroux drills, gave the following results: † Total time in boring and in changing the drills and machines when worn or disabled, 24.3 hours; total length per minute with 6 machines, 2.74 inches; with each machine, .46 inch; number of fresh drills used, 668; number of machines disabled and removed for repairs, 6.3; rock, granitic gneiss.

Works for Reference.—See "Tunneling, Rock-Drilling, and Blasting," Drinker, New York, 1878; in which copious lists of works for reference will be found, and from which extracts have (by permission) been embodied in the foregoing article.

ROCKET. See LIFE-SAVING APPARATUS.

ROLLER. See AGRICULTURAL MACHINERY, and LEATHER-WORKING MACHINERY.

ROLLS. See BREAKERS OR CRUSHERS, and IRON-WORKING MACHINERY.

ROTARY BLOWER. See BLOWERS.

ROTARY ENGINE. See ENGINES, STEAM, STATIONARY (ROTARY).

ROTARY FURNACE. See IRON-MAKING PROCESSES—PUDDLING.

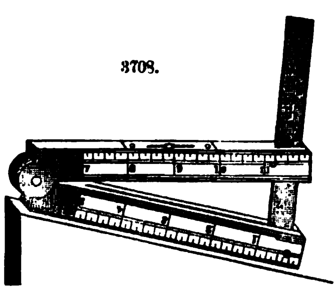
ROTARY PUMP. See PUMPS.

ROUNDING AND STRAIGHTENING MACHINE. See IRON-WORKING MACHINERY.

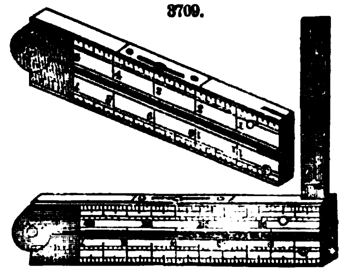
ROVING FRAME. See COTTON-SPINNING MACHINERY, and FLAX, MACHINERY FOR PREPARATION, etc.

RULE. An instrument chiefly used for making linear measurements. It is divided into inches and fractions, and is usually jointed, so that it may be folded up and carried in the pocket. Rules

3708.



3709.



used by some classes of artificers are, however, made in a single piece. A clinometer rule is represented in Figs. 3708 and 3709. In one of the legs is set a small spirit-level, and this leg has a

* Simm's "Practical Tunneling," 3d edition. † Ibid.

pivoted branch folding into a cavity in the other leg; so that the implement may be used as clinometer or slope-level, plumb, square, bevel, protractor, or T-square, and in combination or with a straight-edge as a parallel ruler. Some rules have a slider in one leg; in Gunter's scale this is engraved and graduated with figures.

The use of Gunter's rule is best explained by a description of the line called the *line of numbers*, which is a logarithmic scale of proportions, and enables problems to be easily solved, as shown by the following examples. It is usually divided into two parts, every tenth of which is numbered, beginning with 1 and ending with 10; so that, if the first great division stand for one-tenth of an integer, the next great division will stand for two-tenths, and the intermediate divisions will represent hundredths of an integer, while the large divisions beyond 10 will represent units; and if the first set of large divisions represent units, the subdivisions will indicate tenths, while the second set of large divisions will represent tens, and the subdivisions units, etc. The general rule for using this instrument is as follows: Since all questions are reducible to proportions, if the compass be extended from the first term to the third, the same extent will reach from the second to the fourth term.

Examples.—1. To find the product of any two numbers, as 4 and 8: Extend the compass from 1 to the multiplier 4, and the same extent applied the same way from 8, the multiplicand, will reach the product, 32. 2. To divide one number by another, as 36 by 4: Extend the compass from 4 to 1, and the same extent will reach from 36 to 9. 3. To find a fourth proportional to three given numbers, as 6, 8, and 9: Extend the compass from 6 to 8, and this extent laid the same way will reach to 12, the fourth proportional required. 4. To extract the square root of a number, say 25: Bisect the distance between 1 on the scale and the point representing 25; then half this set off from 1 will give the point 5, which is the root required.

The slide-rule as now constructed obviates the use of the compass. There are two lines of numbers placed one above the other, one of which lines is engraved upon a slide moving in a groove. The mode of use is to place the first term of the proportional upon the slider against the third term on the fixed scale, when the second term upon the slider will stand opposite the fourth term on the scale. (See "The Slide-Rule and How to Use It," Hoare, London, 1866.)

A very accurate rule for ordinary use is made of steel in triangular form. It is not open to the common objection that the edges of rules often become rounded, so that they cannot be approximated sufficiently close to fine work for accurate readings.

Fig. 3710 represents a key-seat rule placed upon a shaft. It is obvious that the edge of the rule will always stand parallel with the shaft, and hence will serve as a guide to mark the lines to denote where a key-way is to be cut.

3710.

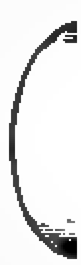
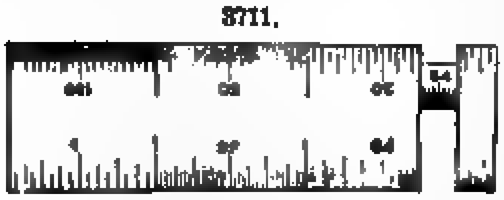


Fig. 3711 shows a caliper rule made by Messrs. Darling, Brown, & Sharpe. The opposite side to that shown in the illustration is divided into 12ths, 24ths, 48ths, 8ths, and 28ths on the outside, and upon the slide into 32ds and 64ths of an inch. When closed, this rule is 3 inches long. The caliper can be drawn out to measure 2¼ inches. The thickness of the rule is one-eighth of an inch. These rules are divided in four ways: A, divided on outside like cut, on slide to 32ds and 64ths; B, divided on outside like cut, on slide to 64ths and 100ths; C, divided on outside to 8ths, 16ths, 32ds, and 64ths, on slide to 32ds and 64ths; D, divided on outside to 8ths, 16ths, 32ds, and 64ths, on slide to 64ths and 100ths. Others are divided for *button gauges*, on outside to 16ths, 20ths, 32ds, and 40ths, and on slide to 40ths and 80ths of inches.

3711.



Pattern-makers use a rule the dimensions of which are made a certain per cent. longer than standard measure. Iron castings shrink on cooling about 1 per cent., or one-eighth of an inch to a foot. The patterns therefore require to be proportionately larger. By using a rule one-eighth of an inch in a foot longer than the standard, every measurement of the pattern is made proportionately larger without the trouble of calculation. When a wooden pattern is made from which an iron pattern is to be cast, the latter being intended to serve as the permanent foundry pattern, as there are two shrinkages to allow for, a double-contraction rule is employed, or one in which the measurements are in excess one-quarter of an inch in every foot, for iron.

RULING ENGINE. See Dividing Machine.

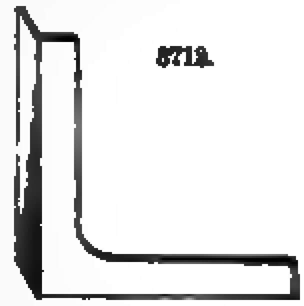
SAFE-LOCK. See Locks.

SAFES for the storage and protection of valuables may be divided into three classes: 1. Fire-proof safes; 2. Burglar-proof safes; 3. Safes both fire- and burglar-proof. The last are usually fire-proof safes inclosing burglar-proof boxes.

Fire-Proof Safes.—The essential requirements of a fire-proof safe are: 1. The generation of steam in the filling, or more properly the safe-lining, for nothing burns within a safe when the filling gives off steam at 212° F.; 2. To continue this generation the longest possible time, in order to save contents during a protracted fire; 3. The maintenance of such properties within the safe as will generate steam when called upon; 4. The prevention of mould or dampness within the safe, or of oxidation to the iron frame of the exterior.

To fulfill these conditions, various substances are used as filling. Safes have been built containing

pipes or cans filled with water, the receptacles being soldered or provided with plugs of fusible metal, which on melting allows of the escape of the water. This combination has not proved successful. Substances containing water, such as alum, have been found more advantageous. Alum contains 50 per cent. of its bulk in water of crystallization, which is readily converted into steam at a high temperature. Among the other materials used for filling are soapstone, alum and plaster, copperas and gypsum, paper-pulp and alum, tiles, alum and clay, asbestos with gypsum, alum, etc., raw cotton, saw-dust and whiting, hydraulic cement, etc.



3712.

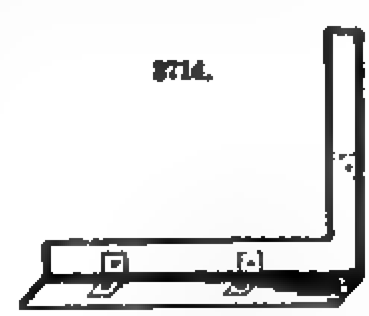
In the construction of the ironwork of a safe, the chief requirement is strength, so that the chest may fall from garret to cellar of the highest building without injury. The thickness of the filling should not be less than six inches; and the hinges, locks, flanges, etc., should be so contrived as to conduct the least possible amount of heat to the interior. Various types of safes of improved construction are described below.

The Butler Fire-Proof Safe has walls of heavy boiler-plate fastened to angle-iron frames, which are welded at the corners so as to be solidly connected, as shown in Fig. 3712. This is claimed to give strength and to prevent bulging or separation of the frame. The top and side angles of the safe are in one piece, and are strongly bolted to the front and back frames. The arrangement of filling in this safe is shown in the sectional view, Fig. 3713, which will serve to represent the general mode of construction of all fire-proof safes. The filling materials in the present case are first two inches of fine cement, and then four inches of alum and plaster. A cup-shaped mass of filling surrounds the lock and prevents conduction of heat thereby.

Marvin's Fire-Proof Safe is made with heavy iron frames welded, the front and back plates being surrounded by a heavy wrought-iron hoop. The side corners are of angle-iron strongly bolted to the hoops and frames, as shown in Fig. 3714. The filling is of dry plaster and alum, the latter material being distributed in lumps throughout the plaster. The doors have four flanges, and close with a tight joint.

Herring's Fire-Proof Safe is constructed substantially similar to the foregoing. The iron-hoop frame, however, is heavier, and is differently bolted to the angle-irons. The body of the safe is of wrought iron. The filling is a double sulphate of lime derived from the residuum of soda-water manufacture. This material is dry and unchangeable at normal temperatures, but at a heat of 1000° F.—red heat of iron—it gives off carbonic-acid gas in large quantities. With this substance plaster of Paris and alum are also used, these materials giving off steam; so that under a high temperature the safe becomes enveloped in an atmosphere of mingled watery vapor and carbonic-acid gas.

Burglar-Proof Safes are of two kinds—either solid or built up. Solid safes are cast in one or more parts; built-up safes, as the name indicates, consist of plates of metal connected to a heavy frame. The best burglar-proof safe is that one which, when attacked, will longest protect its contents. No safe is strictly burglar-proof in the sense that an entrance into it cannot be effected in course of time and with proper tools. The time in which a burglar can work is limited, and rarely exceeds the interval of forty hours or so between Saturday afternoon and the following Monday morning. It is claimed, therefore, for an efficient burglar-proof safe, that it cannot be entered in the above period. The problem to be solved in burglar-proof-safe building is to produce a metal or combination of metals which will resist the hardest drill, will not lose temper under the oxyhydrogen blow-pipe, and cannot be cracked by blows of a heavy sledge; and so to connect the component parts of the structure that they cannot be stripped or torn apart by any mechanical device which a burglar can carry. The arbors and spindles of the locks must also be so constructed that they cannot be driven in or pulled out. The door must fit exactly; the minutest crack around it will offer an entrance for fine wedges. Its joints must be carefully packed to prevent the blowing in of mealed powder



3714.

Of the two kinds of safe above mentioned, those that are built up of plates and frames are by far

the most numerous. There are three principal forms of solid safe: Marvin's, cast in globular form of chrome steel; Herring's, cast from franklinite iron; and Corliss's, made of cast iron surrounding a wrought-iron basket-work. These safes are of limited capacity, as it is difficult to make the necessary large castings without flaws; and it is very doubtful whether they offer the advantages of the built-up variety.

The mode of constructing built-up safes differs with nearly every maker. The materials, however, are the same, namely, hard and soft steel, cast and wrought iron. The steel and wrought iron are made into plates, and these are usually welded together. The frames are generally very massive, and the sets of plates are connected by large numbers of rivets or screws. The construction of various forms of safes is described below.

3715.

The Herring Burglar-Proof Safe, manufactured by Messrs. Herring & Co. of New York, is made as follows: The outside or body of the safe is of wrought iron, or patent high and low steel, welded. The front and back frames, as shown in Fig. 3715, have solid welded angles, and, being finished flush with the body of the safe, offer no joints or crevices for the introduction of a wedge. The sectional view, Fig. 3716, shows the arrangement of the different layers of metal. The outside envelope is of boiler iron; then follow layers of high and low steel, namely: 1, Bessemer low steel; 2, cast steel; 3, Bessemer ductile steel; 4, chrome cast steel; 5, Bessemer soft steel. These plates are piled in a furnace, heated to the welding point, and then rolled into a solid mass. Connected to this series of plates by conical bolts is a plate of iron, then four more plates of high and low steel—all of these layers ranging from one-half to three-fourths of an inch in thickness. The franklinite plate which follows is the distinctive feature of the Herring construction. Franklinite is a mineral composed of peroxide of iron, oxide of zinc, and oxide of manganese, and is found in Sussex Co., N. J. The pig iron produced is almost identical in character, appearance, and structure with the best lamellar iron made from the spathic ores of Siegen and Müsen in Germany. Its fracture shows large and brilliant silver-white lamellar facets, sometimes beautifully crystallized, and so hard as to cut glass. The iron is melted, and to form the plate is poured around a wrought-iron basket-work. In it are placed the rivets which receive the innermost ⅝-inch iron plate. All of these layers of metal are secured together by conical bolts with steel heads, which do not pass directly through the safe and are irregularly placed. A strong tongue is fixed all round the door, projecting from its inner surface. A similar tongue is made on the jamb of the safe, against which the door closes. This tongue is made to fit inside of the tongue projecting from the inside surface of the door, so as to form a groove or channel all around the doorway, to receive the projecting tongue on the door. In this groove or channel is placed a packing, so that when the door is closed by means of a cam-hinge it keys the whole structure, and the sides cannot be caused to spring or bulge from the edges of the door by wedging. The rubber packing makes an air-tight joint, and protects against the introduction of explosives.

Probably the most severe tests to which any system of burglar-proof construction has ever been subjected were made on a representative section of the Herring safe on Oct. 1–8, 1879, by Park Benjamin's Scientific Expert Office of New York, expressly for this work. The trials were conducted by Mr. Richard H. Buel, C. E. The plate furnished for test was 12 in. square, and was composed of

3717.

alternate sections of hard and soft steel welded together, franklinite, and a lining of soft iron. The thickness of the various materials was as follows: Steel, 2.6 in.; franklinite, 2.1 in.; soft iron, 0.42 in.; total thickness, 5.12 in. Drills of the best hardened steel were used. These were held in a drill-press, the feed of which was worked by two men. It was determined that no impression could be made on the franklinite under a pressure of 4,000 lbs., and the maximum working pressure was 12,000 lbs. Under these pressures, time not being taken into account, a hole five-eighths of an inch in diameter at the beginning and one-half of an inch at the end was made in the franklinite portion.

The regular test, limited to 24 hours' consecutive work, was begun on October 1st, the effort being to make a hole 1½ in. in diameter through the section. The outer soft-steel portion of the plate was readily penetrated with the drill, but the tool was stopped on reaching the inner layer of hardened steel, the only effect of increased pressure being to wear away the drill. This result occurred whenever, in passing through the steel strata, a layer of hard steel was reached. By applying the flame of a powerful compound blow-pipe, however, the temper of the steel was drawn and the material was rendered soft enough to be penetrated. In the test under consideration the plate was heated 31 times, and the blow-pipe was in use for 6 hours and 5 minutes. The time employed in actual drilling was 3 hours and 2 minutes, making a total period of 9 hours and 7 minutes used in piercing the steel. Three experienced men were employed at the drill-press, one at the ratchet, and two at the feed, and acting as reliefs at the lever. This was essential, as, although the ratchet-lever was 3 ft. in length, the labor of working it under heavy pressure was so great that one man could operate but for a short time before becoming fatigued. The following table shows: 1, the actual drilling time employed on each day, by which is meant the exact period intervening between the insertion of the drill and its removal, and the time during which the blow-pipe was used; 2, the working time, which includes the foregoing and also that consumed in cleaning out the hole after the drills had been broken in it, making measurements of penetration, etc.; 3, the progress made in penetration; and 4, the number of drills used:

3718.

DATE.	Actual Drilling Time.		Working Time.		Penetration.	Number of Drills used.
	Hrs.	Min.	Hrs.	Min.	Inches.	
October 1	2	56	8	50	0.9375	14
" 2	6	9	7	59	1.5125	34
" 3	4	6	4	29	0.26	17
" 4	3	1	3	36	0.14	13
" 5	3	25	4	10	0.47	22
" 7	5	48	6	40	0.54	34
" 8	0	17		17	0.09	1
Totals	25	41	30	08	3.59	125

It was considered as proved that no burglar could duplicate the conditions under which the test was made, and that, despite the advantages of these, the failure to pierce the franklinite by more than .25 of an inch was entirely due to the refractory nature of the materials used in the construction.

Two views of Herring burglar-proof safes are given in Figs. 3717 and 3718. Fig. 3717 represents

the burglar-proof banker's chest, showing three chests, one within the other. Fig. 3718 shows the construction of a bank-vault door, the vault itself being built of masonry.

Marvin's Burglar-Proof Safe, made by Marvin & Co. of New York, is represented in section in Fig. 3719. It is made with solid wrought-iron angle frames welded at all corners, with alternate plates of wrought iron and five-ply welded steel and iron combined. Each plate is confined in place by heavy steel and iron screws, with heads pointing inward. No two screws are allowed to come in line. The plates are held together by heavy steel-headed conical bolts, with nuts on the inside, over which the end of the bolt is riveted. To prevent entrance through the walls by drilling a single layer at a time, and introducing powder to blow it off, all the interstices between the plates are filled with cement which hardens with age. The corners are lapped with welded steel and iron. The door has a double tongue and groove constructed so as to operate without the crane-hinge. The spindles and lockwork are made drill-proof, and are built into the doors with shoulders as shown.

3719.

The Butler Burglar-Proof Safe.—Fig. 3720 represents a section of the safe manufactured by the Butler Safe Company of New York. It is constructed of alternate plates of steel and iron welded together, with the corners made solid and bent. The plates are connected by bolts, rivets, and screws, which are made of iron and steel welded and twisted. The spindle is made in two parts, and is of the same material as the body of the safe. The outer portion of the spindle enters the door half-way, and operates on the inner part, which passes through the remainder of the door. It is impossible to drive this spindle in, as half the body of the door is behind it.

Burglars' Implements.—The tools used by burglars in effecting entrance to safes are the jimmy, wedges, and drills. The jimmy is simply a short steel bar, having its point bent to a right angle or curved, and flattened sufficiently to enter a moderate-sized crack. It serves as a lever to wrench open doors or pull plates asunder. A sectional jimmy is the ordinary tool, with a handle composed of sections which are screwed together. Tools of this kind have been captured measuring 11 ft in length, the leverage gained by which is of course enormous. In attacking a safe by the door, the burglar usually attempts to introduce powder. To this end he putties the crack carefully except at two places a couple of inches or so in length each. At one of these he affixes a cup or trough, to which is connected a rubber pipe leading to a small portable air-pump. In the other aperture he inserts a thin card on which mealed powder is slowly poured. By operating the air-pump, the air is exhausted in the safe, and the powder is gradually drawn in around the door. It remains only to apply the match, and the door is blown outward, either torn from its bolt-work or else bulged so far as to admit of the introduction of a jimmy and its easy wrenching off. Where powder cannot be used, the burglar attempts wedging. The wedges are simply small pieces of oak or steel, which are driven into the crack until an opening sufficient for the introduction of jimmies is effected. Drills are always of the finest tempered steel, and are often employed in connection with the blow-pipe, which is used to draw the temper and thus soften the plates. When a small hole is once made in the safe, the introduction of a dynamite cartridge speedily blows off the door.

G. H. B.

SAFETY-LAMPS. See Lamps, Safety.

SAFETY-VALVE. See Boilers, Steam.

SAND-BLAST. A process by which common sand, powdered quartz, emery, or any sharp cutting material, is forced or blown upon the surface of any brittle substance, through which means the latter is cut, drilled, or engraved. It is the invention of Mr. B. F. Tilghman of Philadelphia. A jet of sand impelled by steam of moderate pressure, or even by the blast of an ordinary fan, depolishes glass in a few seconds; wood is cut quite rapidly. With a jet issuing under a pressure of 300 lbs., a hole has been cut through a piece of corundum 1¼ in. thick in 25 minutes. A blast of emery containing iron ore has abraded a black diamond weighing 1.2607 grain, so that the latter showed a loss of .0369 grain in 8 minutes. Prof. Osborn Reynolds has analytically examined the principles involved in the process. (See *Philosophical Magazine*, 4th series, xlvi., 337; also "Report of U. S. Commissioners to Vienna Exposition of 1873 (Engineering)," vol. iii., 318.)

In order to protect surfaces which it is desired shall not be abraded, it is only necessary to cover that portion with a stencil of malleable or tough material, such as lead, iron, rubber, leather, or even paper. To this list of so-called stencil materials may also be added, as the result of recent experiments, rubber-paint or ink.

The apparatus in which the blast is produced is constructed and operated as follows: Resting upon a framework, and inclosed in a box-like apartment, is a smaller box, open at the top and with slanting sides, which is filled with the ordinary quartz-sand. At the bottom of this box is a long slit, through which the sand flows into the blast-chamber below. The end of the slit is just below the main blast-pipe, which leads in from the right. At the bottom of this slit is a device by which the sand is conveyed into the blast-chamber, and yet the blast is not allowed to force its way upward. This blast-chamber has a curved side, and within this the blast is maintained at such a pressure as the nature of the work demands. The sand, having fallen into this receptacle, is at once forced by the pressure of the blast down through a second and still narrower slit below, and passes out from it in the form of a long, thin sheet. The glass plate to be acted upon is placed upon a shelf at the left and before the opening. A series of small belts, moving over rollers, serve as carriers to the plate, which by them is slowly conveyed out of sight and beneath the sheet of falling sand. The instant the sand particles come in contact with the polished surface of the glass, the work of "grinding" begins, and soon the glass plate appears at the opposite side with a rough but regularly depolished surface. The sand in the mean time falls or is blown into a receptacle below, from which it is removed by the aid of a screw and hoppers to the box above, to be used over again, so long as the feeding in of the glass plates is kept up. The rate at which these plates travel beneath the sand varies from 6 to 30 in. a minute, according as the nature of the work demands. Where it is desired to cover the plate with a pattern, it is evident that the stencils may be adjusted to it before its introduction into the machine. Illustrations of this apparatus will be found in *Appletons' Journal*, July, 1875.

Applications of the Sand-Blast.—The sand-blast has been applied to the cleaning of metal castings and sheet metal; the graining of zinc plates for lithographic purposes; the frosting of silver-ware; the cutting of figures on stone and glass for jewelry; and the cutting of letters and devices on monuments, tombstones, etc.

Engraving on glass by the blast is conducted as follows: Having been laid down on a low, flat table, the plate is covered over its whole surface with a thin layer of tin foil. Upon this bright metallic surface the artist sketches lightly any desired design. The lines of this sketch are made with a pencil, and thus appear black. The plate with its coating of tin is then removed, and placed over a gently-heated surface, where it receives over its entire face a thin layer of melted wax. This latter is sufficiently transparent to permit the lines of the sketch to be seen beneath it. When the wax has hardened, a third artisan, by the aid of a sharp knife, cuts down through the wax and foil along the lines indicated. This being accomplished, the foil, with its coating of wax, is pulled off from that portion which it is desired to grind or depolish, leaving the rest covered. It is now only needed to place the plate with its stencil surface upon the bands or carriers of the machine, and the whole rapidly passes under the sand, and the work is finished; that is, the exposed portions are ground, while those parts covered with the tin sheet and its wax coating are untouched. A pliable rubber paint is also used, by the aid of which letters and designs are printed on thin paper, and the whole sheet thus prepared is placed on the glass plate. The force of the blast tears away the unprotected paper, while that portion which has received the rubber ink is untouched, and thus the surface beneath it is unground. It may be seen how, by this method, work may be rapidly duplicated.

The department best illustrating the delicacy with which the sand may be made to do its work, is that of copying engravings or even photographs. It is stated that photographic negatives in bichromated gelatine, from delicate line engravings, have been thus faithfully copied on glass. In photographic copies in gelatine, taken from nature, the lights and shadows produce films of gelatine of different degrees of thickness. A carefully-regulated sand-blast will act upon the glass beneath these films more or less powerfully, in proportion to the thickness of the film, and the half-tones or gradations of light and shade are thus produced on the glass.

One of the most important recently-discovered applications of the sand-blast is to the cutting of files. Mr. Tilghman has found that by subjecting worn files to the action of the jet, the cutting edges are rapidly renewed, and the file is made sharper than when new. The process is as follows: A stream of fine sand, impelled at a high velocity by a jet of steam, is applied to a file at an angle of from 10° to 15° from its face, the file being moved about so that all parts may be acted on. The sand for the purpose is very fine grit prepared by washing and settling. It is used in the state of very soft slime drawn from a receiver. The effect upon the teeth of a file which has become dull by wear is to grind away some of the metal from the inclined sides of the teeth, so as to reproduce a cutting edge. A comparative trial of the cutting power of sharpened files was made, with the following results: A piece of soft wrought iron was filed clean and weighed; 1,200 strokes were made by a skilled workman with one side of a new 10-inch bastard file, the iron was again weighed, and the loss noted. The other side of this file was then subjected to the sand-blast for five seconds, and 1,200 strokes were

made with this sand-blasted side on the same piece of iron, great care being taken to give strokes of equal length and pressure in both cases. The iron was then weighed, and the loss found to be double as much as in the first case. These operations were repeated many times, counting the strokes and weighing the metal each time, and the quantity cut was found to gradually become less for both sides as these became worn. When the weight of metal cut away by 1,200 strokes of the sand-blasted side was found to be no greater than had been cut by the first 1,200 strokes of the ordinary side when quite new, a second sand-blasting was applied to it for 10 seconds, and in the next 1,200 strokes its rate of cutting rose to nearly its first figure. When the cut made by the ordinary side of the file fell to about four-tenths of its cut when new, it was considered by the workman as worn out, and a new file of the same size and maker was used to continue the comparison with the one sand-blasted side; 83 sets of 1,200 strokes each and 13 sand-blastings were made on the same side of this file, and in that time it cut as much metal as six ordinary sides. In 99,600 strokes it cut away 14 oz. avoirdupois of wrought iron and 16.4 oz. of steel. With an equal number of strokes its average rate of cutting was, on wrought iron, 50 per cent. greater than the average of the ordinary sides, and on steel 20 per cent. greater. As the teeth became more worn, the time of the application of the sand-blast was lengthened up to one minute. After the thirteenth resharpening, its rate of cutting was nine-tenths that of the ordinary side when quite new. When the teeth become so much worn that the sand-blast ceases to sharpen them effectively, the file can be recut in the usual way, and each set of teeth can be made to do six times as much work as an ordinary file, and to do it with less time and labor, because it is done with edges constantly kept sharp. The time required to sharpen a worn-out 14-inch bastard file is about four minutes, or proportionately less if sharpened before being worn entirely out. Smooth files require much less time. About 4 horse-power of 60-lb. steam used during four minutes, and one pint per minute of sand (passed through a No. 120 sieve), and the time of a boy, are the elements of cost of the operation.

SAW-GUMMER AND SAW-SWAGE. THE SAW-GUMMER is a device for cutting away the plate

3721.

of a saw in order to deepen the spaces between the teeth. This operation is done either by grinding or cutting, or by punching.

Fig. 3721 represents Mixter's New England saw-gummer, which consists of a frame clamped as shown upon the saw. Moving upon ways in the frame is a carriage in which is an arbor carrying the cutter, and rotated by the crank *A*. *B* is the feed-wheel, which turns the screw that presses the cutter up against the blade. By turning the crank *A* the cutter is caused to abrade the metal, and thus to deepen the spaces between the teeth. Saw-gummers are also made with emery-wheels instead of cutters. (See EMERY-GRINDING.)

Fig. 3722 represents a saw-gummer made by Messrs. Snyder Brothers of Williamsport, Pa. The machine consists of a heavy cast-iron stock supporting a die. A punch is also provided, worked by the eccentric hand-lever shown. The end of the punch is partially cut away so as to leave a long tongue or projection, which is not drawn out of the die even when the punch is fully raised. The object is to support the punch and keep it from springing while cutting.

Saws should be filed, gummed, and swaged on the under or face side of the teeth; and care

should be taken not to gum below the line or circle of the back of the teeth. The teeth should be worn back around the saw.

THE SAW-SWAGE is an instrument for spreading the teeth of saws. An adjustable device of this kind is shown in Fig. 3722 A. The body of the apparatus has two fixed and diverging jaws, *F* and *G*, the latter of which comes in contact with the under side of the saw-tooth, and is made convex in form. Through the body, at the intersection of the inner faces of the jaws, is a circular hole in which fits the round portion of a movable jaw *H*. *I* is a temper-screw bearing on jaw *H* so as to adjust it to different angles with relation to the face of the lower jaw. *J* is a saw-tooth inserted in position. In operation, the jaw *H* is adjusted as shown and firmly held in position. Blows are then struck with a hammer at the other end of the body hard enough to upset the tooth and give it the desired form and sharpness at the cutting edge.

SAWS. A saw is an instrument made of a thin plate, sheet, or strip of metal, having a notched or serrated edge which rasps or files away the material cut, forming a groove termed the kerf.

Manufacture of Saws.—Plates for saws are made of ingots of steel rolled to proper thickness. For circular saws this varies from one-thirty-second to one-fourth of an inch, according to purpose, and the diameter from 3 to 100 inches. The plate is sheared to a round shape, and is submitted to a vigorous hammering to reduce the uneven surface. The centre- and pin-holes are then bored, and the teeth are measured, marked out, and cut by a powerful fly-press. The tempering which follows is done in oil, to which other ingredients are added, these last being kept secret by manufacturers, each one of whom usually has his own method of preparing the bath. The temperer's difficulties are augmented by the great difference in the degree of hardness required by the various sections. As a rule, the harder the wood to be cut, the tougher the temper of the saw; but it must in all cases stop short of brittleness, or else, while being upset, the teeth will crumble instead of spreading.

The plate when tempered is usually of a dark-blue color (see TEMPERING AND HARDENING), covered with scales, and to a greater or less extent warped by the heat. It is therefore straightened on an anvil, after the method described under HAMMERS, HAND. This operation requires great care and judgment. The saw is then fastened centrally upon a shaft, and caused to rotate rapidly against a large grindstone moving in an opposite direction, which dresses off one side to a perfectly uniform surface, when the blade is turned and the other side similarly treated, making the blade slightly thinner toward the centre than at the circumference. The saws are again tested as to planeness, the straightening process repeated if necessary, and the final polishing is done by wooden blocks coated with glue and emery.

Straight saws are made in a similar manner, regard being had to the difference in shape. The edge intended for the teeth is trimmed true, the teeth are punched by a fly-press, filed, tempered, wiped, heated until any remaining oil blazes off, hammered on an anvil or *smithed*, ground to a gradually decreasing thickness from front to back (this is now done on both sides at once), rehammered, again ground or drawn, glazed or polished, again straightened on the anvil, grained with emery, the teeth set, the blade stiffened by a heating process, any discoloration thus occasioned removed by acids, and finally oiled. The French method of saw-making consists in rolling the blades cold several times, in order to render the grain close and the metal homogeneous, and then heating them in special furnaces from which the air is carefully excluded. The saws are next plunged in a bath of colza oil in a dark chamber, and tempered by the aid of machines which cause them to pass between cast-iron plates heated to a fixed temperature, according to the nature of the article to be produced.

Detailed descriptions of saw manufacture will be found in the *Scientific American*, xxv., 355, and xxviii., 231.

SAW-TEETH may be divided into three classes: cutting teeth, sawing teeth, and intermediates. Cutting teeth perform their functions by paring the wood; sawing teeth act by first cutting a line on each side of the kerf and then removing the unsupported centre by scraping; while the intermediates perform more or less of both these functions. Cutting saws are applied to slitting or ripping purposes, and sawing ones to cutting across grain; and yet the action of the two is in one respect identical—that is to say, in both instances the teeth sever the fibre of the kerf from the main body of the wood before attempting to entirely dislodge it. In a slitting saw the rake is all in front of the tooth, because the cutting duty is in front; and in the cross-cut, the rake is on the side, because the duty is there also, the advance and cutting edge operating at a right angle to the length of the fibre of the wood. The word "pitch" when employed by the saw-maker almost always designates the inclination of the face of the tooth, up which the shaving ascends, and not the interval from tooth to tooth, as in wheels and screws. The teeth of some kinds are usually small, and seldom so distant as half an inch asunder; these are described as having 2, 3, 4, 5, to 20 points to the inch. Such as are used by hand are commonly from about ¼ to 1¼ in. asunder, and are said to be of ½ or 1¼ in. *space*, although some of the circular saws are as coarse as 2 to 3 in. and upward from tooth to tooth.

The processes denominated *sharpening* and *setting* a saw consist, as the names imply, of two distinct operations: the first being that of filing the teeth until their extremities are sharp; the second that of bending the teeth in an equal manner, and alternately to the right and left, so that, when the eye is directed along the edge, the teeth of rectilinear saws may appear exactly in two lines, forming collectively an edge somewhat exceeding the thickness of the blade itself. In general the angles of the points of the saw-teeth are more acute the softer the material to be sawn, agreeably to common usage in cutting tools; and the angles of the points and those at which the files are applied are necessarily the same. Thus, in sharpening saws for metal, the file is generally held at 90° both in the horizontal and vertical angle, as will be shown; for very hard woods, at from 90° to 80°; and for very soft woods, at from 70° to 60° or even more acutely. The vertical angle is about half the horizontal.

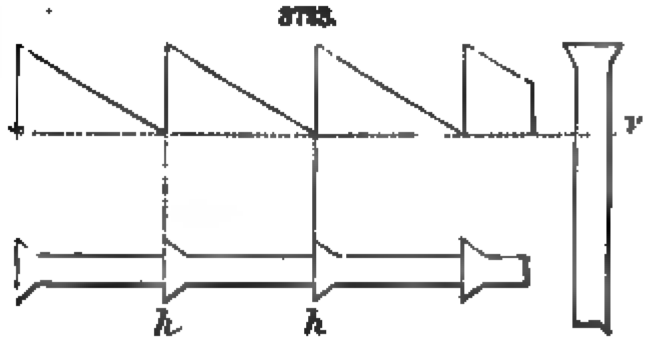
Fig. 3723 represents in plan and two elevations the saw-teeth that are the most easily sharpened, namely, those of the frame-saw for metal, commonly used by the smith: the teeth of this saw are

not set or bent in the ordinary manner, owing to the thickness and hardness of the blade, and the small size of the teeth. The smith's-saw blade, when dull, is placed edgewise upon the jaws of the vise, and the teeth, which are placed upward, are slightly hammered; this upsets or thickens them in a minute degree, and the hammer-face reduces to a general level those teeth which stand highest. They are then filed with a triangular file held perfectly square, or at 90° to the blade, both in the horizontal direction *h*, and the vertical *v*, until each little facet just disappears, so as to leave the teeth as nearly as possible in a line, that each may fullfill its share of the work.

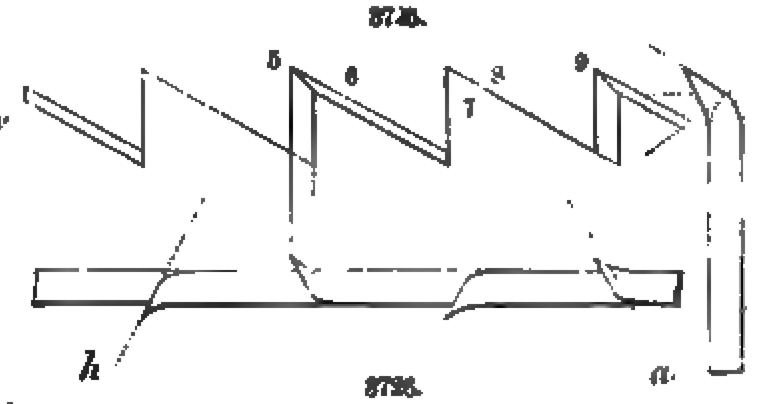
The most minute kind of saws, those which are made of broken watch-springs, have teeth that are also sharpened nearly as in the diagram, but without the teeth being either upset or bent; as in very small saws the trifling burr, or rough wiry edge thrown up by the file, is a sufficient addition to the thickness of the blade, and is the only *set* they receive.

Fig. 3724 illustrates the peg-tooth; but it may also be considered to apply to the M-tooth, and, in part, to the mill-saw tooth. The points of the cross-cutting saws for soft woods are required to be

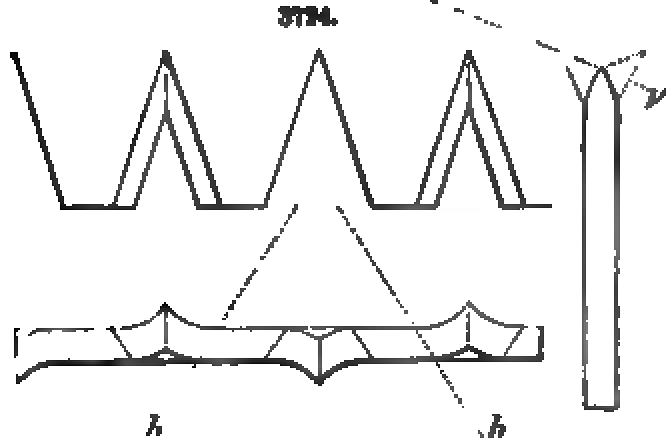
3723.



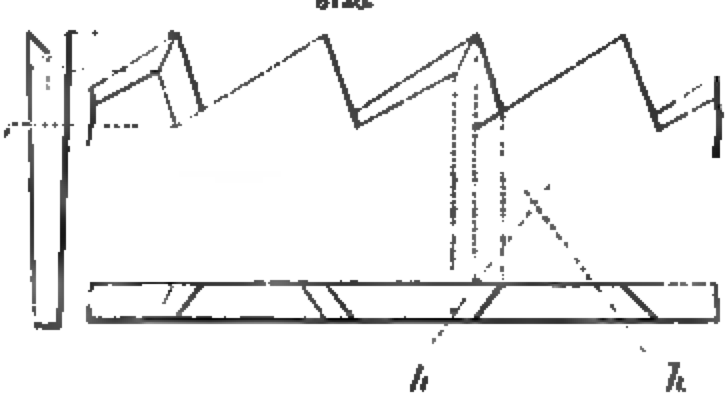
3725.



3724.



3726.



acute or keen, that they may act as knives in dividing the fibres transversely. The left sides of each alternate tooth are first filed with the horizontal angle denoted by *h*, and then the opposite sides of the same teeth with the reverse inclination, or *h'*. Fig. 3725 may be considered to refer generally to all teeth the angles of which are 60° (or the same as that of the triangular file), and that are used for wood. The most common example is the ordinary hand-saw tooth; but teeth of upright pitch, such as the cross-cut saw, or of considerable pitch, are treated much in the same manner. The teeth having been topped, the faces 5, 9 are first filed back, until they respectively agree with a dotted line *a*, supposed to be drawn through the centre of each little facet produced in the topping; the file is then made to take the sides 6 and 7 of the nook until the second half of the facet is reduced, and the point of the tooth falls as nearly as may be on the dotted line *a*. The first course takes the face only of each alternate tooth; the second course the back of the former and face of the next tooth at one process; and the third course takes the top only of the second series, and completes the work. This order of proceeding is employed, that the faces of the teeth may be in each case completed before the tops or backs.

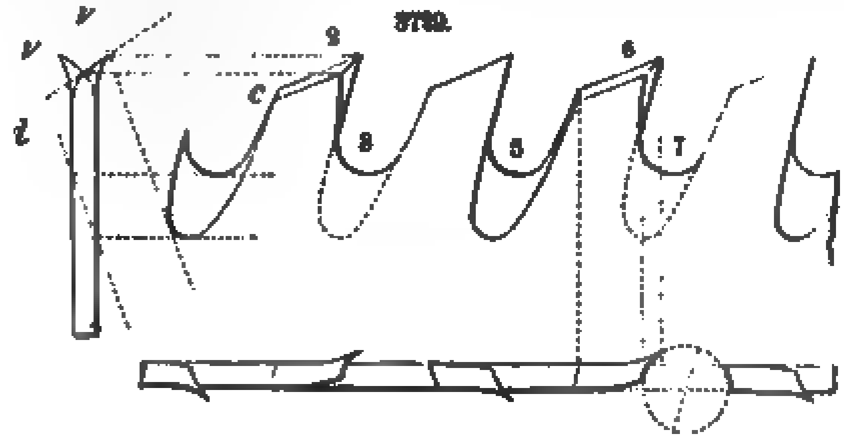
Fig. 3726 exhibits also in three elevations a somewhat peculiar form of tooth, namely, that of the pruning saw for green wood. The blade is much thicker on the edge than the back, so that the teeth are not set at all. The teeth are made with a triangular file, applied very obliquely as to horizontal angle, as at *h*, sometimes exceeding 45°, but without vertical inclination, as at *v*; and the faces of the teeth are nearly upright, as in the hand-saw. The large sides of the teeth are very keen, and each vertical edge is acute like a knife, and sharply pointed; in consequence of which it cuts the living wood with a much cleaner surface, and less injury to the plant, than the common hand-saw tooth.

The construction of the tooth of the Lightning saw, made by Mr. E. M. Boynton of New York, is shown in Figs. 3727 and 3728. It will be noted from Fig. 3727 that the teeth may be considered as generated by the placing of two saws as ordinarily constructed side by side, as shown. The method of

sharpening the teeth is indicated by the lines in Fig. 8728. The advantages claimed are that these, with their opposite cutting faces cutting in line, are equivalent to the front cut both ways of a hand-saw, in distinction to the two back cuts of the V-saw. Hence increased speed is gained. All the teeth, moreover, being of even length, double-pointed, cut with outside vertical and projecting edges, and clear simultaneously with the same

Fig. 8729 explains the method employed in sharpening gullet or brier teeth; in these there are

8729.



large curvilinear hollows, in the formation of which the faces of the teeth also become hollowed so as to make the projecting angles acute. The gullets, 3, 7, are first filed; and from the file crossing the tooth very obliquely, as at $v v$, in the section, the point of the tooth extends around the file, and gives the curvature represented in the plan. The file should not be so large as the gullet; it is therefore requisite that the file be applied in two positions, first upon the face of the one tooth, and then on the back of the preceding tooth. The tops of the teeth, 2, 6, are next sharpened with the flat side of the file, the position of which is of course determined by the angles c and d; the former varies with the material from about 5° to 40° with the edge, and the latter from 80° to 60° with the side of the blade; the first angles in each case being suitable for the hardest, and the last for the softest woods. The alternate teeth having been sharpened, the remainder are completed from the other side of the blade, requiring in all four ranges.

For machines for filing saw-teeth, see *Scientific American*, xxviii., 231.

Principles of Setting Teeth.—After sharpening, the saw is to be *set;* that is, a uniform bend is given to the teeth alternately to the right and to the left. This is often done by a hammer and set-punch, but usually by a saw-set, which consists of a narrow blade of steel, with notches of various widths for different saws. The saw is firmly held in clamps; the alternate teeth are inserted a little way into the proper notch, and are then bent over by raising or depressing the handle of the blade. Some sets are arranged with a guide by which the bends are made uniform.

8730.

SAWS, BAND. The band-saw is composed of a ribbon of steel brazed or soldered at the ends so as to form an endless band, with the saw-teeth cut upon one edge. The mechanical device employed to drive the saw is composed of a framework carrying an upper and a lower wheel, and over these two wheels the band-saw is stretched. The lower wheel is driven by power, so that the band-saw on the cutting side is pulled, which tends to keep it straight on that side. To keep the saw strained to a proper degree of tension, the journal-bearing or bearings of the upper wheel are made adjustable, and are acted upon by either a weight or a spring.

The chief requisites of band-saw blades are uniformity of temper, width, and thickness, a perfect joint, and freedom from all flaws. They are liable to break from crystallization, imperfect tension, or carelessness of the operator in handling; and as a certain degree of temper is required for springs made of fine steel, so is the same temper necessary in band-saw blades to secure durability and efficiency. The appearance of a band-saw blade does not indicate its temper, and it is difficult to distinguish tempered from untempered saws. A

soft saw is comparatively worthless, as it will not retain its cutting edge. The best test is to bend the blade and determine whether its elasticity indicates temper.

Originally the band-saw was employed only for cutting light outside curves, but at the present time its use has become widely extended, and it is employed for general sawing purposes even of the heaviest nature.

For brazing band-saws muriate of zinc is used. It is prepared by dissolving metallic zinc in muriatic acid until no more is taken up. The acid is then diluted with rain or condensed-steam water, when it is ready for use. Borax water for soldering or brazing—the borax serving as a flux—is made by burning a sufficient quantity of the salt in an iron dish, pulverizing it, and boiling in rain or condensed water to the consistence of cream. The lap of the saw-ends should be from $\frac{3}{4}$ to $1\frac{1}{4}$ inch, according to the thickness of the plate, and the sides should be beveled to form a smooth point.

There are numerous difficulties attending the use of the band-saw, which it is the object of modern improved construction to overcome. Thus, when the lower band-wheel is suddenly set in motion, often at a speed of 450 revolutions per minute, the upper wheel must at once attain the same number of turns, or the saw-blade—a delicate thin steel ribbon, in the smaller and most commonly used classes of saws—will slip. The strain on the blade is thus increased, the saw is unduly heated, and crystallization of its material is apt to occur, and the covering of the wheels is damaged. Again, when the saw begins work or is stopped, the upper band-wheel carrying its momentum may overrun the lower wheel, thus creating undue tension on one portion of the band. Means are always necessary for taking up the slack of the blade when it expands by heat; and for this purpose automatic devices are requisite.

One of the most ingenious and effective appliances used to overcome the difficulties first mentioned is that used by Messrs. Bentel, Margedant & Co., of Hamilton, Ohio. This consists of a cast-steel band covered with leather, which moves and revolves in a recess formed in the rim of the upper driving-wheel. When the machine is set in motion, the steel band slides in the recess, and sets the upper band-wheel gradually in motion. On the other hand, when the saw is abruptly stopped, the momentum of the upper wheel causes it to slide forward in the band until the speed or momentum of both wheels is equalized. In the same machine is a neat device for changing the strain on the saw-blade in two ways, by sliding a weight on a lever from or toward the fulcrum, and by establishing a different fulcrum and distance of leverage by moving the fulcrum-bolt. There is also a novel arrangement of lateral and back-thrust guides, the former being of wood, and placed on each side of the saw so that they can be adjusted to compensate for wear, and the latter being a series of steel balls and washers placed in a cylindrical inclosure. The back of the saw comes in contact with the balls, which rotate.

In the band-saw represented in Fig. 3730, the front saw-guide is counterbalanced so that it may be readily adjusted in height. The bearing of the upper band-wheel is of rubber, and cushioned to provide the elasticity necessary to accommodate the varying lengths of the saw under different temperatures. The table is constructed of wood in sections to prevent its warping, and may be set out of the horizontal for sawing tapers.

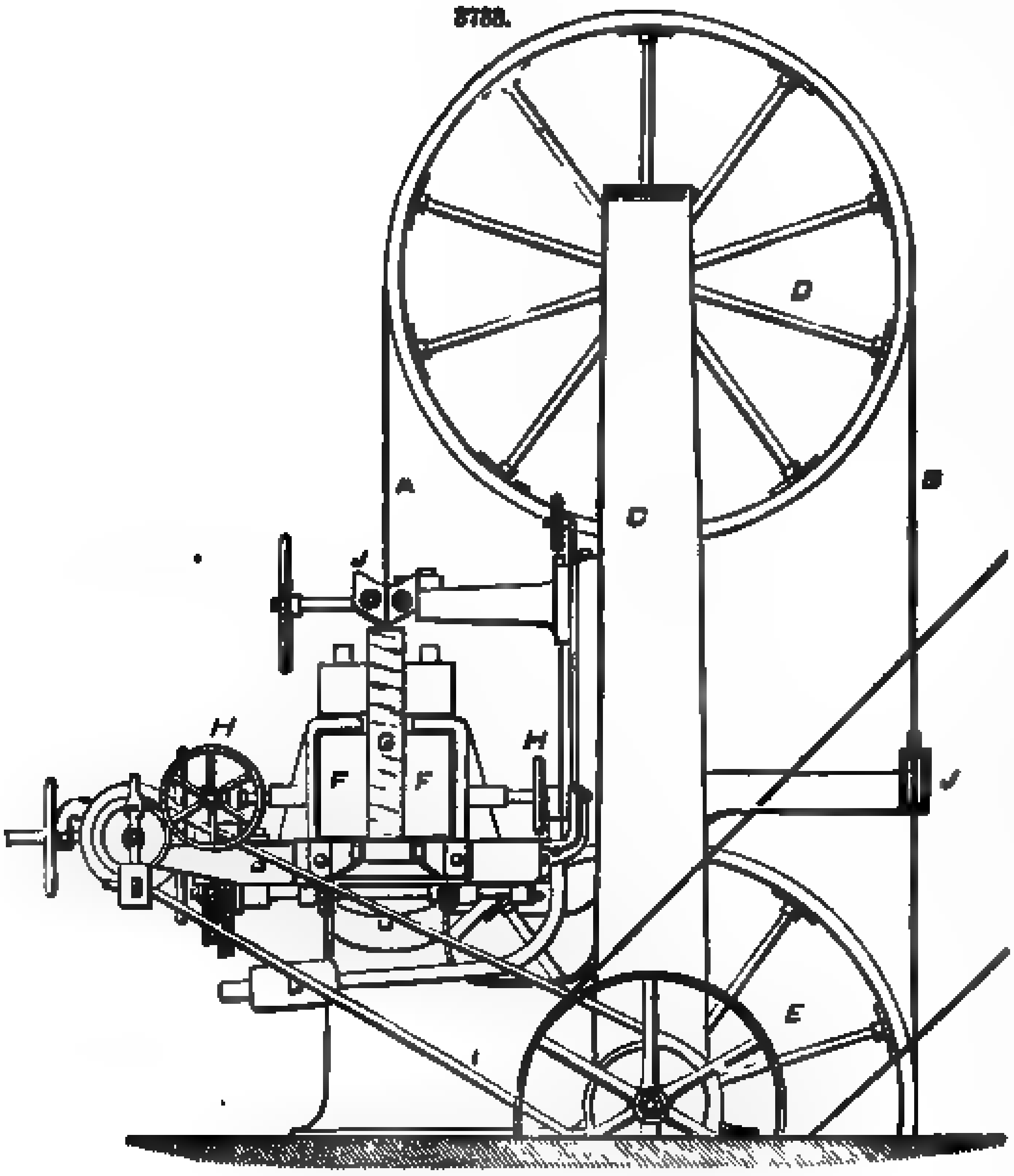
Fay's Band-Saw.—Fig. 3731 represents a band-saw manufactured by Messrs. J. A. Fay & Co. of Cincinnati. The upper wheel is of elastic steel, and has a vertical movement controlled by the hand-wheel and screw shown. The vertical guide-bar, which receives the pressure of the work, is provided with a steel roller which receives the back thrust of the saw in revolving, and relieves the back of the saw from friction. A roller of similar character is placed below the table. The weighted lever which supports the upper wheel and creates the necessary tension of the saw, in combination with the rubber coverings of the wheels, furnishes a compensating

—— ...he length of the saw by heat or sud-
ion of the wood, or greater pressure

e *Work.*—A large machine for band-
2 and 3733. *A B* is the saw: *C* is
g wheels, which are 6 ft. in diameter
ought iron covered with bent walnut
ng of canvas and gutta percha, the
heels an amount of elasticity which
ne extent the changes in the length
tions in its temperature, and further
through heavy work without undue
er being cut, which is fed to the
lers, adjusted to suit the thickness
of the board or plank to be sawn
H, which operate screws actuating
rying the rollers *F F*. *I* is a belt
d-motion by means of the gearing
shown. *J J* are guides to steady
the band-saw.

One of the largest band-sawing machines yet constructed is that erected for Mr. Van Pelt of New York by the late firm of Richards, London & Kelley, of Philadelphia. The saw is 55 ft. long, from 4½ to 6 in. wide, and 15-gauge thick. The pulleys are 75 in. in diameter, with hubs of wrought iron, and are mounted centrally on the main column of the framing, so as to equalize the strain upon the saw and prevent its springing, and also to economize its weight. They are covered with a lagging of pine wood, over which is glued an envelope of heavy harness leather. The bearings for the wheel-shafts are 4 in. in diameter and 12 in. long.

3733.



Arbey's Band-Saw.—In Fig. 3734 is represented a band-sawing machine constructed by F. Arbey of Paris, France, for large timber. The timber is supported on a carriage traversing over fixed rolls. The tension of the saw is regulated by the band-wheel shown at the back of the frame, which wheel operates a screw, which in turn through the medium of a nut causes the head and journal-box carrying the upper wheel to traverse the slide provided to the upper part of the frame. The saw is sustained both above and below the timber by the guides shown.

Band Saw for cutting Iron.—A machine of this class has been constructed in Europe, and will be found described in *Engineering*, xviii., 174. The construction is heavier than is usual in wood-sawing machines, but other-

wise there are not many points of difference. The saw-band is maintained at the desired tension by means of a vertical screw turned by a hand-wheel, on which is mounted the sliding block carrying the upper wheel. A further adjustment is also provided at the back of the machine.

Band-Saw for Stone.—In this, as in the straight saw, the cutting is accomplished by diamonds set in the blade. The latter is an endless flexible metallic belt, running upon an upper and lower pulley. To one edge of this belt are affixed settings of steel at short intervals, in which are held the diamond cutting points. These diamonds are the teeth that do the work, and they are so set as to cut a kerf that will entirely clear the saw-blade or belt from contact with the stone. The machine, as shown in Fig. 3735, consists of a massive bed-frame which rests upon a foundation of masonry, and adapted to support a double movable table, which carries the stone to the saw. These tables are fed by a system of gearing from the upper spindle, moving them at the rate of a fraction of an inch to 12 in. per minute, thus providing for the work upon stone of varying degrees of hardness and of various sizes. It has a strong upright frame to carry the upper and lower pulleys, which is also provided with means of giving adequate tension to the band-saw. Vibration is prevented by suitable guides, and a circular disk running at the back of the blade prevents both cutting and friction at that point. This apparatus is reported to have cut 8 in. of brown stone in 3 minutes, running at a speed of 4,500 ft. per minute. The stone block was 10 ft. wide, 12 ft. long, and 5 ft. thick.

SAWS, CIRCULAR. One of the main difficulties in the use of a circular saw is that of maintaining its tension equal under varying velocities and temperatures. The method employed by the saw-straightener to compensate for the expansion due to the centrifugal motion is to place upon the saw a tension insufficient to dish the saw when at rest, and yet sufficient to accommodate the expansion due to the centrifugal force. If the tension is insufficient to accommodate the centrifugal force, the saw becomes loose in the middle, or, in other words, it becomes rim-bound when in motion; and the result is that it dishes, so that one side comes in contact with the work. If the saw-teeth meet with different resistances on its two sides (which may occur from the waves in the grain of the timber, or from other causes), the dish will jump from one side to the other of the saw. To steady circular saws, adjustable guides are usually placed beneath the saw-table of the machine; but if a saw becomes unduly heated, its evenness of tension is impaired, and it must be rehammered.

Dished Saw.—Fig. 3736 represents Boynton's dished circular saw, made for cutting out crooked pieces of wood, such as chair-frames, felloes, etc., and circular pieces from boards. The tool is chiefly adapted to the uses of wheelwrights and cabinet-makers.

Slotted Saws.—Circular saws are constructed under Lockwood's patent by Messrs. Curtis & Co. of St. Louis, Mo., with slots running from the eye outward, as shown in Fig. 3737. It is claimed that if the saw be heated at or near the eye, the slots close up as much as the metal expands, thus leaving the edge of the blade unaffected. If the edge of the saw be heated and consequently expanded,

3738.

3737.

3739.

the slots by opening neutralize the expansion, and both edge and eye remain true. The efficiency of this device seems to be well demonstrated.

Circular Saws with Inserted Teeth.—The Planer-Toothed Saw.—Fig. 3738 represents a section of the saw-plate containing Emerson's planer-tooth. The clamp pieces *A* and wedges *B* hold the teeth *C* firmly in position. The pieces *A* have shoulders at *D*, against which the inner ends of the shanks of the teeth bear. *E* is a finished tooth shown separately. The tang or shank is formed by a drop-hammer and die, leaving the outer end (which is slightly hooked) and the edges to be of the full width of the flat face of the bar. Cutting edges are thus formed which cut the width of the kerf and plane each of its sides.

In Fig. 3739 is shown the lumberman's clipper-saw, made by Messrs. Emerson, Smith & Co., of Beaver Falls, Pa. The method of inserting the teeth is obvious. This construction is claimed to be especially suited for thin saws, the advantages of which will be apparent when it is remembered that every sixteenth of an inch saved in saw-kerf saves 1,000 ft. of lumber in each 16,000 ft. of inch-boards sawed.

The following practical data relative to the use of circular saws are given by Messrs. Kingsland, Ferguson & Co., of St. Louis, Mo. A thick saw will stand a higher motion than a thin one; but a motion of 10,000 ft. per minute on the periphery of the saw is as fast as a saw ever ought to be run. A taper saw will stand a higher motion than an even gauge, for the reason that the rim is lighter and the expansion from centrifugal force will be less. The number of teeth depends upon the amount to be cut at a revolution, providing the power is ample; but if the power is deficient, the cutting should

be adapted to the power available to drive the saw. To get the greatest cutting capacity, put in all the cutting points possible, and at the same time have sufficient throat-room to chamber the saw-dust. A 72-inch saw with 48 teeth, cutting 4 in. to a revolution, removes 128 sq. in. on a full cut of a 32-inch board. This solid wood cut into saw-dust will require twice the space, or 256 in.; and each tooth should have $5\frac{1}{3}$ sq. in. throat-room, to work free and easy and clean freely; with less throat it will clog or force the saw-dust into the space between the saw and the log, and cause it to heat on the rim. For small logs a larger number of teeth is preferable, because the distance each tooth cuts is less, and does not require so much room for dust. A saw is less likely to heat when it is cutting its full capacity, cleaning freely, than when it is cutting along slowly in the log. A good saw requires no paper packing. See that the track is level and straight; that the saw-shaft is level; that the saw hangs plumb; that it goes on the mandrel easy, and is a close fit; that the lug-pins fit and have a bearing; that the tight collar is a little concave, and the loose one straight; that the saw is perfectly straight on the log side when it is screwed up ready to run; that it is in line with the carriage, or a little inclined toward the log; that the saw is perfectly round; that the throat-room is equal to the amount to be cut to each revolution of the saw; that the backs of the teeth are not too high, and that they are filed perfectly square; if a swaged tooth be used, see that the teeth are swaged out so as to have a sufficient clearance for the body of the saw; that there is little or no end play to the saw-shaft; that the guides are perfectly adjusted; that the journals of the saw-shaft are properly packed; and that the motion is not too high. If the saw inclines to run out of the log, give it a little lead in; and if it inclines into the log, lead it out by filing the points of the teeth, or adjusting the mandrel. If it runs out and in, or, as it is termed, is "snaky," lead into the log and file the points of the teeth to lead out. This will force that part of the saw from the mandrel to the cutting point in a direct line, and hold it there. The cause is, that the saw is large on the rim, and trying to hold it to line with the guide-pins only makes it worse. When the guide-pins are once adjusted, when the saw is cool do not move them, as there is where the saw should run. Reducing the set of the saw so that the centre of the saw will warm a little with the friction, causing it to expand, is better. If the saw heats in the centre, give it more set; if it heats on the rim, either the backs of the teeth are too high, or an attempt is being made to cut more than the saw will chamber, forcing the saw-dust between the saw and the log. If the saw is tight on the rim, increase the motion if possible, as this expands the saw on the rim and gives set enough to keep it cool in the centre.

Power required for Circular Saws.—The horse-power required to drive circular saws running empty, according to Hartig's experiments, is represented by the formula $P = \frac{n\,d}{32000}$, in which d = the diameter of the saw in inches, and n = the number of revolutions per minute. The net power required to cut with a circular saw is proportional to the cubic contents of the material removed, at the rate of 1 horse-power for 1 cubic foot per hour of soft wood, or for half a cubic foot of hard wood. We therefore have the formulas: Power for circular saw for hard wood $= \frac{A\,c}{6}$; for soft wood, $\frac{A\,c}{12}$; in which A = the sectional area of surface in square feet cut through per hour, and c = width of cut in inches.

Table of Speed for Circular Saws.

Size of Saw.	Rev. per Min.	Size of Saw.	Rev. per Min.	Size of Saw.	Rev. per Min.
8 in.	4,500	30 in.	1,200	52 in.	700
10 in.	3,600	32 in.	1,125	54 in.	675
12 in.	3,000	34 in.	1,058	56 in.	650
14 in.	2,585	36 in.	1,000	58 in.	625
16 in.	2,222	38 in.	950	60 in.	600
18 in.	2,000	40 in.	900	62 in.	575
20 in.	1,800	42 in.	870	64 in.	550
22 in.	1,636	44 in.	840	66 in.	545
24 in.	1,500	46 in.	800	68 in.	529
26 in.	1,384	48 in.	750	70 in.	514
28 in.	1,285	50 in.	725	72 in.	500

Tests of Circular Saws.

Table showing Best Results of Trial of Circular Saws at Cincinnati Industrial Exposition, 1874.

CONTESTANTS.	Kind of Wood.	Diameter of Saw.	Revolutions per Minute.	No. of Teeth.	Gauge: Eye.	Gauge: Teeth.	Gauge: Kerf.	Size of Log.	No. of Boards.	Time.	Square Feet of Lumber.	Horse-Power Indicated.	Feed.	Perfect Boards.	Imperfect.	Square Feet Lumber per Minute.	Per Cent. of Power Used.
Emerson, Ford & Co.	Poplar	56	615	50	6	7	8	20 × 20	16	2.44	800	120.16	2[illegible]	12	4	109.7	.718
Emerson, Ford & Co.	Oak.	56	610	50	6	7	8	16 × 16	12	1.48	176	121.68	8[illegible]	10	2	102.5	.778
Emerson, planer-tooth.	Poplar.	56	590	34	7	8	8	20 × 20	16	3.17	800	112.89	2[illegible]	4	12	116.9	.848
Emerson, planer-tooth.	Oak.	56	632	34	7	8	8	16 × 16	12	2.27	176	114.24	2[illegible]	..	12	100.5	.1000
R. Hoe & Co., solid-tooth.	Poplar.	56	519	36	5	8	8	20 × 20	16	2.09	800	112.18	4[illegible]	8	8	189.5	.527
R. Hoe & Co., chisel-tooth.	Poplar.	66	605	36	5	7	2	20 × 20	16	2.45	800	114.78	8[illegible]	8	8	109.1	.689
R. Hoe & Co., chisel-tooth.	Oak.	56	602	36	5	7	2	16 × 16	12	1.58	176	9[illegible].82	[illegible]	12	..	90	.720

CIRCULAR SAWING MACHINES are constructed to be operated either by hand or power.

Hand or Foot Machines.—A description of Weaver's hand-power machine will be found in the

Scientific American, xxvi., 414. Mr. L. S. Fithian of New York has devised an ingenious arrangement of multiplying gearing which enables the power of the operator applied to a treadle to be stored up, so that it may drive either circular, jig-, or band-saws. A description of the circular sawing machine so constructed—in which it is claimed that 40 steps on the treadle, after the machine is set going, correspond to 4,080 revolutions of the saw—will be found in the *Scientific American*, xxvi., 366. Extensions of the principle to band- and jig-saws appear in the same, xxviii., 79 and 306.

Power Machines.—The form of power circular saw usually employed in ordinary workshop manipulation is shown in Fig. 3740, which represents a design by First & Pryibil of New York. By means of gauges or guides, against which the work may be rested while being traversed over or past the saw, a variety of work may be performed, such as cutting pieces to any required angle or taper. In some cases the table is made to adjust to an angle with the plane of rotation of the saw, thus sawing the work at an angle. In all of this class of machines the top of the saw is employed to cut grooves or rabbets; and to regulate the depth, the height between the top of the saw and the face of the table must be made adjustable. This may be accomplished by raising one end of the table, or, as in Fig. 3740, by carrying the saw-spindle in a swing-frame pivoted at one end and adjustable for height at the other, being locked in position by the lever, screw, and quadrant shown.

3740.

Circular Resawing Machines.—In Fig. 3741 is shown a circular resawing or slitting machine, employed to recut lumber to the required size for the market, or for special manufacture. The lumber is fed through the vertical feed-rollers; and to separate the stuff behind the saw, so as to relieve the sides of the saw from friction, the diagonal vertical wedge shown behind the saw is employed. The mechanical means by which the self-acting feed is operated is as follows: The countershaft shown running across the machine is belted as shown from the main or saw spindle. On the other side of the machine, and upon the same countershaft, is a pulley connected by belt to a pulley fast upon the shaft to which the pinion *A* is attached. *A* operates the gear shown, which in turn gives motion through bevel-gears to the upright shaft *B*. Upon this latter, and beneath the table, is a gear-wheel operating gear-wheels attached to the spindles of the upright feeding rolls, the latter being supported at top and bottom by the brackets shown, and regulated for various widths of timber by sliding upon the cross-slide on which they operate, the adjustment being made by means of the handles shown.

THE LANE AND BODLEY SAW-MILL.

A portable circular-saw mill, by Lane & Bodley of Cincinnati, is shown in Fig. 3742, and in a full-page plate. The frame carrying the saw-spindles is of iron, which is bolted to a wood framing. The timber-carriage and sills are of wood, bolted together, so as to form a strong foundation. *A* is the mill-frame, carrying the main saw-spindle *B* in the bearings *C C*. *D* is a wedge-roller to spread the board from the log behind the saw. *F* is a friction-wheel for operating the carriage on the back traverse. *G* is a friction-wheel for operating the timber-carriage on the forward traverse. *H H* are the feed-cone belt-pulleys. *I* is the main belt-pulley for driving the saws. *J J* are standards to carry the top saw and its attachments. *K* is the hand-wheel for operating the screws by which the position of the top saw is adjusted. *L* is the carriage for the timber. *M* is the track whereon the carriage traverses. *N N* are the head-blocks or bearers whereon the timber rests. *O O* are screws operating the silling bars *R R*. *P P* are ratchet gear-wheels operating *O O*. *Q Q* are pawls to operate the ratchet-wheels *P P*. *U U* is a swivel for the automatic dogs which grasp the timber. *V V* are the hooks for the above dogs, which are operated by the hand-wheels shown. *W* is the belt tightener. The upper saw-spindle is driven by belt from the lower one. The object of providing an upper saw is to enable the cutting of larger-sized timber without the employment of such large saws as would otherwise be required. It will be observed that the teeth of the upper saw are in an opposite direction to those on the lower one, and as a result the grip of the upper saw upon the timber acts to pull the log forward, thus relieving the strain of the feed by assisting the feed-motion. The object of having two friction-pulleys for the carriage traverse is, by the employment of a larger driver, to traverse the carriage quicker on the back motion and thus save time. This class of machine is peculiarly of American design, and is intended to be moved from place to place, following the location of the timber in the lumber districts.

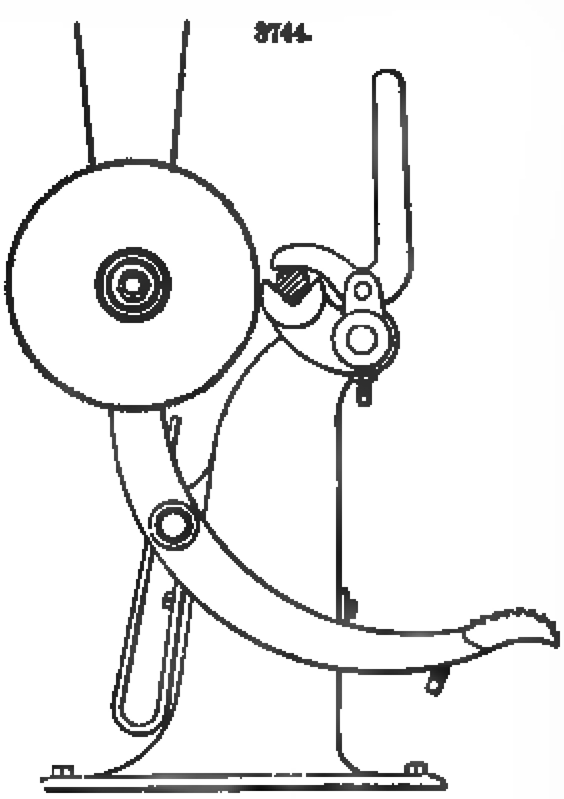
Double Circular-Saw Mill.—Fig. 3743 represents the Empire Mill made by Messrs. Kingsland, Ferguson & Co., of St. Louis, Mo. It will be noticed that two saws are here employed, a larger one below and a small one above. The objection to mills of this class is the quivering of the top saw and the difficulty of keeping it in line. This is claimed to be obviated by the construction of the top frame in the present mill, which runs in an iron sleeve and may be easily adjusted. It can be quickly raised or lowered, thrown in or out, or any lead given to the saw while running. That portion of the iron sleeve which comes in contact with the iron uprights, and that portion of the latter on which it works, are both planed true. In raising or lowering the top saw, the sleeve moves on this planed surface, thus obviating the necessity of moving the whole top frame when it is desired to change the position of the top saw. The "top rig" is bolted together and braced by the angle given to the uprights, and it is claimed that even when at the highest speed the saw runs perfectly steady. The feed consists of square-faced pulleys, alternately wood and iron, acting directly on each other. The face of these pulleys is wide enough to give surface for friction to drive the largest logs without slipping. The "rosser" *A* is driven from the top shaft, and is used for removing bark, sand, etc., from the log, in advance of the saw, and so saving wear of the latter.

CIRCULAR SAWS FOR METAL.—For cutting bars of metal into lengths, the machine shown in Fig. 3744 is employed, the operation of which is sufficiently apparent to render a description unnecessary. It may however be noted, that instead of a steel saw, a sheet-iron or steel disk may be employed. It must be revolved at as high a velocity as is practicable without danger of its bursting from the

centrifugal force due to its rotation. The operation of such a disk is that of softening the metal by the heat generated from the contact of the edge of the disk with the metal being cut, the latter being abraded and falling in white-hot shreds. Machines of this kind are now largely employed for cutting cold bars of metal. (See *Engineering*, March 17, 1878.) For a saw for cutting hot iron, moving at a circumferential speed of 7,875 ft. per minute, and making a cut 0.14 inch wide, the power required, according to Hartig, is for red-hot iron 0.702 time, and for red-hot steel 1.013 time the sectional area of the surface cut through in square feet.

Machines for Sawing Iron.—The ordinary hot saw, for sawing iron at a bright red heat, differs but little from a common circular wood-saw. The plate is made heavier, and the teeth shorter or are wanting. A recent improvement in sawing iron is the use of the cold saw, for sawing any section of iron while cold. This consist simply of a plain soft steel or iron disk without teeth, about 42 in. in diameter and three-sixteenths of an inch thick. The velocity of the circumference is about 15,000 ft. per minute. One of these saws will saw through an ordinary steel rail cold in about one minute. In this saw the steel or iron is ground off by the friction of the disk, and is not cut as with the teeth of an ordinary saw. Fig. 3745 is a fair representation of one of these saws adapted to cutting off a rail.

3744.



Reese's Fusing Disk.—This is an application of the cold saw to cutting iron or steel in the form of bars, tubes, cylinders, etc., in which the piece to be cut is made to revolve at a slower rate of speed than the saw. By this means only a small surface of the bar to be cut is presented at a time to the circumference of the saw. The saw is about the same size as the cold saw above described, and it is rotated at a velocity of about 25,000 ft. per minute. The heat generated by the friction of this saw against the small surface of the bar rotated against it is so great that the particles of iron or steel in the bar are actually *fused*, and the "sawdust" welds as it falls into a solid mass. This disk will cut either cast iron, wrought iron, or steel. It will cut a bar of steel 1½ in. diameter in one minute, including the time of setting it in the machine, the bar being rotated about 200 turns a minute. (Patent 159,448, February 2, 1879.)

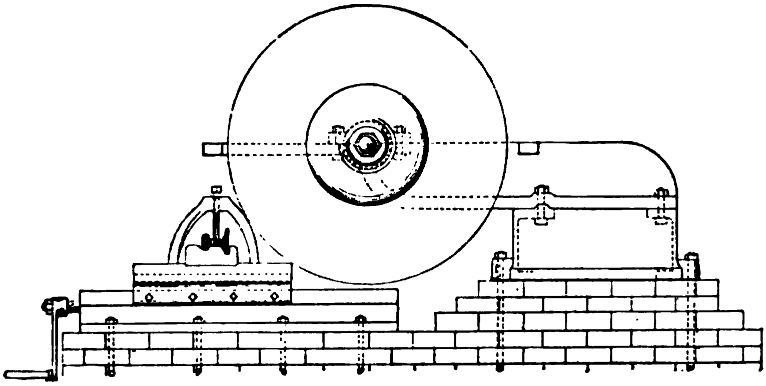
CIRCULAR SAWS FOR STONE-CUTTING are heavy steel disks having inserted diamond teeth. The Stone Monarch saw (see *Scientific American*, xxxv., 191) cuts in various kinds of stone from 1 to 36 in. per minute or per 10,000 ft. run of saw. A 66-inch saw contains 84, and a 20-inch saw 60 diamonds. These are held in steel or iron holders made in two parts, and provided with soft-metal cushions on which the diamond rests. The holders are dovetailed into the edge of the saw-disk.

In Emerson's saw (see *Scientific American*, xxxi., 159) the diamond is first wrapped in a casing of copper, which is pressed around it. A cavity is formed in the steel holder, and the diamond and its

casing are forced therein. A circular saw 73 in. in diameter carries 48 diamonds. Hardened steel points are used for all stone up to that of the hardness of ordinary grindstone. The speed of the saw is from 5 to 500 revolutions per minute, and the feed of stone to the saw may be varied from one-sixteenth of an inch to four inches at each revolution.

VARIOUS ARRANGEMENTS OF CIRCULAR SAWS.—*The Swing-Saw* consists of a circular saw arranged in a suspended swinging frame and operated by a belt. By means of a counterweight the frame may

3745.



be caused to remain stationary in any desired position within the range of the swing, and it may be moved out of the way when not in actual use.

Bracket Cutting-off Saw.—The saw-carriage slides on ways attached beneath a bracket, which sets out from a heavy plate fastened to a wall or other support. The bracket is adjustable vertically, and the carriage, by means of a rack and pinion connected with the band-wheel in front, has a traverse movement toward or from the wall and over the table.

Moulding Saw.—An ingenious form of saw for cutting figured mouldings has been devised, in which the blade is a spiral of the desired shape and has its cutting teeth on the edge. The metal is exceedingly thin. The blade screws its way along the edge of the wood and cuts at the same time.

"*Drunk Saw.*"—This name is given to a circular saw held in beveled collars so as to "wabble." It is sometimes employed to cut mortises, it being competent to form a kerf over an inch in width.

Shingle-sawing machines are described under SHINGLE MACHINERY.

For *cylinder saw*, see BARREL-MAKING MACHINERY.

SAWS, RECIPROCATING OR STRAIGHT. I. SINGLE SAWS.—*Hand-Saws.*—With regard to the

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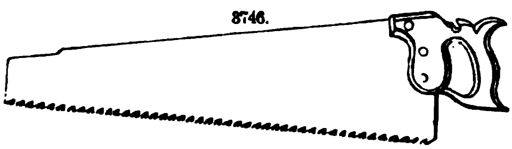
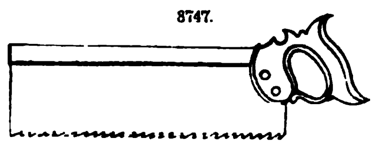


3747.



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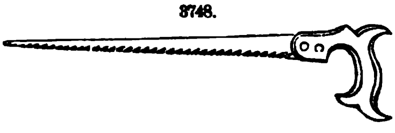

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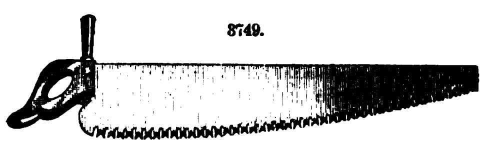
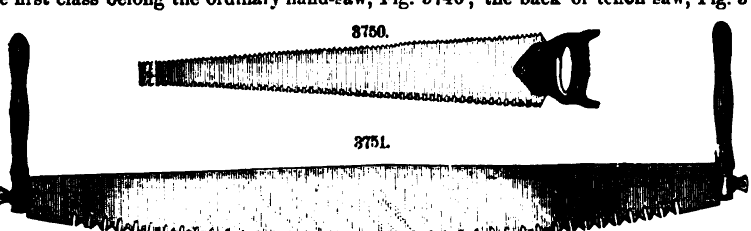


mode of holding the blade, two classes of hand-saws may be noted: 1, those held in handles secured at one extremity of the blade or both; 2, those strained and fastened at both ends in brackets.

To the first class belong the ordinary hand-saw, Fig. 3746; the back or tenon saw, Fig. 3747; the

3750.

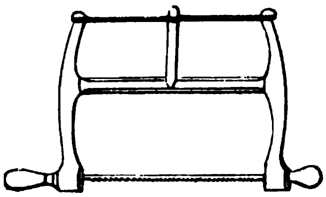
3751.



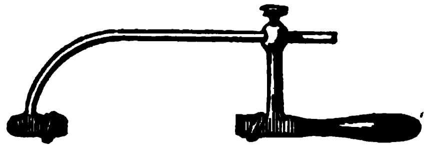
compass saw, Fig. 3748; and the ice-saw (see ICE-HARVESTING APPARATUS). Fig. 3749 is Boynton's lightning cross-cut saw; Fig. 3750 a double-edge saw, and Fig. 3751 a large double-handle cross-cut

saw, by the same maker. The double-edge saw may be used in places where a wide saw cannot be inserted; and having its handle at the centre of the blade, at the wide end and directly in line with the teeth, the draught is rendered direct, and cutting made easy both at the forward and backward motions. The Boynton doubled-handled saw, Fig. 3751, is especially adapted for fast cutting. At the

3752.



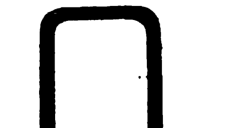
3753.



Centennial Exhibition two men with one of these saws cut off a sound log of gumwood, one foot in extreme diameter, in seven seconds, or at the rate of a cord of wood in five minutes. The construction of the teeth of these saws is explained on page 695.

BRACKET-SAWS.—To the second class belong the bracket-saws shown with two forms of handles in Figs. 3752 and 3753, and the bow-saw and the frame-saw for metal or ivory, Figs. 3754 and 3755.

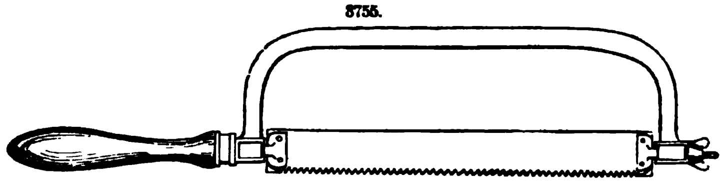
3754.



Mitre-Box.—Hand-saws of the first class are guided to cut at an angle in mitre-boxes. An improved device of this kind is represented in Fig. 3756, in which the blade is guided on vertical spindles placed at the extremities of an arm, which may be adjusted in any desired position in a horizontal plane. The frame is of cast metal. Rollers on the spindle support the saw. By slightly raising or lowering the spindles, when necessary, leaden rolls at the bottom may be adjusted to stop the saw at the proper depth; and by the use of a set-screw, the spindles on which the guides revolve may be turned sufficiently to make the rollers bear firmly on the sides of a saw-blade of any thickness.

MACHINE SAWS.—*Jig-Saws* are short saws operated reciprocally with a very quick motion. They are employed upon small or delicate work only, and are to be found mainly in pattern-making, joinery, or cabinet-makers' shops. The principle of the machine is to operate the saw in opposition to the tension of a spring, and thus to obtain a rapid movement with as small an amount of shock as possible; and for this reason all the parts are made as light as is consistent with strength. The saws are held in hooks or an equivalent at one end, so that the blade may be passed through a hole in the work and then attached to the machine. By this means the saw will cut out spaces that do not find exit at the outer edges of the work. The springs are usually made strong in proportion to the duty, and with a comparatively small amount of movement; and hence the spring obtained from a wood lever is frequently met with,

3755.



and from its wide adaptation appears to meet the requirements as nearly as the conditions admit. The jig-saw shown in Figs. 3757 and 3758 is the pattern made by Richards, London & Kelley, intended for fret and perforated work. It is constructed wholly of metal, and the table is adjustable horizontally for bevel-sawing. The foot shown at the base is attached to a friction-brake, whereby the saw may be instantly stopped. The small foot shown around the saw is to prevent the work from lifting with the upward movement of the saw. The head, carrying the upper end of the saw, is adjustable in the slide (by means of the hand-wheel shown) to accommodate different lengths of saws. The motion is given by the crank-disk, and is imparted to the guide carrying the lower end of the saw through the medium of the connecting-rod. The crank-pin is adjustable in distance from the centre of the crank-disk, to vary the length of the stroke. The frame being boxed (that is, hollow) gives to the machine a maximum of rigidity in proportion to its

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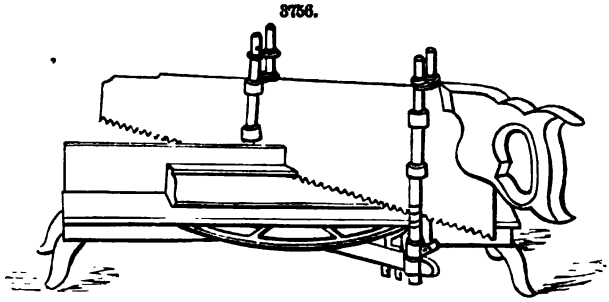

weight, and thus avoids as far as possible the jar or shock which is so objectionable in and inherent to this class of machine.

The so-called scroll-sawing machine is a jig-saw employed for cutting out scroll-work with very fine saws. It is usually operated by foot-power, the saw being held at each end after the manner of a jig-saw. In Fig. 3759 is shown Stafford's improved form of this machine, in which, instead of the saw being passed through the work and fastened top and bottom, it is held in guides at top and bottom and fastened at the top only, thus facilitating the insertion of the saw, while at the same time preventing its retreat or spring from the work under either a front or a side pressure. This enables

3757. 3758.

the saw to operate under the most delicate and adverse conditions, and makes it possible to use saws so fine as to turn exceedingly sharp corners. The saw is driven by a crank; is provided with a small blower to blow the dust from the surface of the work; and has a drilling attachment, which is placed in operation by a slight lateral movement of the driving-belt, which is operated by treadle from below. There are numerous saws of this kind in the market, chiefly designed for amateurs' use in fret-sawing. (See "Fret-Sawing for Pleasure and Profit," New York, 1877.)

Drag-Saws are cross-cut saws in which the effective stroke is on the pull-motion. They are employed for cutting logs, and are operated by simple mechanical contrivances to which power is communicated by belting or other convenient means. Fig. 3760 represents a saw of this type manufactured by Snyder Brothers of Williamsport, Pa. The saw is reciprocated by a pitman and crank, and is secured to the end of a sliding bar as shown. The blade is supported by a guide suspended from above. It is claimed that this saw will cut through a 3-foot pine or cypress log in one minute when properly handled, and will cut enough blocks for 80,000 shingles per day.

Messrs. Ransome & Co. of Chelsea, England, have constructed a drag-saw directly connected to a steam-engine and designed for felling trees. Using a 4-horse-power portable engine at a pressure of from 60 to 80 lbs. of steam, the saw made from 250 to 300 strokes per minute, and, it is reported, cut down four elm trees, averaging 3 ft. in diameter, in 45 minutes. (See *Engineer*, Jan. 25, 1878).

Mulay or Muley Saw.—This name is derived from the German *Mühlsäge*, mill-saw. The saw is straight, and is not strained in a gate or sash, but in sliding carriages or muley-heads which move in guides on the frame of the mill. In Snyder Brothers' Empire muley-saw hangings, represented in Fig. 3761, wooden blocks on the upper end of the saw run in adjustable guides, and are so long that they can be made to run very loose and yet not allow the saw to get out of line. The speed of this saw is about 330 revolutions a minute at a maximum. The report of a competitive test furnished by the manufacturers shows that in 11 hours and 50 minutes it cut 18,279 ft. of lumber, over one-third of this amount being one-inch boards, and the remainder two-inch plank.

Gang-Saws.—A gang-saw consists of a number of parallel saw-blades arranged in a gate, the object being to rip the log into planks at one passage along the ways. Various names are given to large saw-mills of this kind.

"Round" and "live" gangs are synonymous terms. In the East and Pennsylvania they are called round gangs, and in Michigan and the West live gangs; and the terms are used to designate gang-saw mills in which the whole log is fed through and sawed into boards or deals at one operation. "Slabbing" gangs are those in which there are no saws in the centre of the frame, so that, after the

log has passed through, the two sides are sawed into boards or plank, but the centre remains and is called a stock, and is flat on two sides. A "saddle" slabber is one in which the logs are carried forward while resting on narrow carriages called saddles. A saddle slabber does not saw as fast, but makes straighter stocks than the live gang. The log is fed forward by spike-rollers, and supported on special trucks, called a clamp and a bear-trap. These flattened logs or stocks are then taken to the "flat" gang and sawed into boards or plank. Lumber sawed upon a slabber and flat gang is straighter and nicer than that sawed upon a round or live gang. A "pony" gang is a small flat gang, used for sawing thin boards out of the best quality of timber. The term "stock gang" is employed for saws which make regular market lumber, as distinguished from dimension lumber, which is sawn to specific sizes as ordered.

Snyder's Gang-Saw Mill.—Figs. 3762 and 3763 represent a live gang manufactured by Messrs. Snyder Brothers of Williamsport, Pa.

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3760

der Brothers of Williamsport, Pa. From an iron bed or frame, resting on masonry or piles, rise heavy iron upright frames B, secured by cross-pieces. One cross-piece is represented as partially removed. On the inner sides of the frame-castings B are the guides on which the frame D runs, and in which the saws are hung. This frame is connected at its lower end by a pitman E to the wheel-crank on the main shaft, on which is a pulley and fly-wheel. By this mechanism, the saw-gate or frame D has a reciprocating motion imparted to it. On each side of the frame are rollers A with teeth, called spike-rollers, which are made to revolve by gearing on their ends, and feed the log up to the saws. The front end of the log C is placed on the lower spike-roller A; the other end is supported on a truck F called a bear-trap, and held in place by two arms having long teeth, which are forced into the log L, holding it firmly. The truck has flanged wheels running upon an iron track. When the log is partially sawed, and the end being cut into boards or plank, the truck G,

3763.

called a clamp, is run under it. On this truck are two upright jaws geared to a right and left screw, by which the arms are forced up against the side of the sawed log and pinch it lightly. At *H* are pressure-rolls called "binders." Their pressure is regulated by the weighted levers *I I*. The feed is driven and regulated, first, by the eccentric *J* on the crank-shaft, which connects with a round rocker-arm, on which slides a box *K* connecting at its upper end to a rocker. By this combination the rocker-arm is made to vibrate to a greater or less degree as the block *K* is moved on its arm by the lever *L*. The feed-wheel (called "rag-wheel") *M* has a V turned into its outer edge, and at the outer end of the arm is a V-shaped cam or dog which fits into this V-groove. When this arm moves down, a dog moves loosely along the groove in the rag-wheel. At the same time the frame *D* with its saws is moving up. When the arm moves up, the dog is forced into the V in the wheel, carrying it round, and by suitable gearing turning the rolls and feeding the log forward, as the frame *D* and its saws are moving down and doing its cutting. This is what is known as a friction-jab feed. Some gangs are built with a continuous feed. In that case, the saws must be overhung so as to clear the wood while it is moving up.

A round or live gang of this class, with saw-frame 42 inches wide clear, will saw about 50,000 feet of one-inch white-pine board in 10 hours. A flat gang of the same width will saw about 60,000 feet in the same time.

Arbey's Gang-Saw Mill.—Fig. 3764 represents a gang-saw mill constructed by M. F. Arbey of Paris, France. The timber is held in clamps on carriages traversing rails or ways. Motion is given to the saws through the medium of the fly-wheels, which carry crank-pins to which are connected the rods that communicate with the saw-gate. The rods are of wood with metal bearings. A chain-feed is provided, operated by a pawl upon a catch-wheel, and is thus intermittent. It is regulated by adjusting the height of the rod operating the slotted arm (carrying the pawl) from the centre of the catch-wheel, which rod receives motion from an eccentric on the driving-shaft.

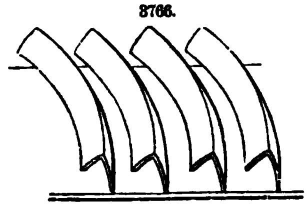
Stone-Saws.—For sawing marble into slabs, steel blades are suspended in swinging gates or frames vibrated by hand or power, usually the latter, and a plentiful supply of sand and water is delivered to the kerf. Talloch's machine for this purpose is represented in Fig. 3765. The blades are adjustable as to distance apart, and are vibrated by the connecting-rod shown. Water and sand are supplied as follows: Above the block of marble to be sawn is fixed a water-cistern, or trough, extending across the whole width

of the frame. A number of small cocks are arranged along each side of the cistern, and a small but constant stream from each of the cocks is received beneath in a little box; a sloping channel leads from every box across the bottom of a trough filled with sand, which mingles with the water

and flows out in separate streams, that are conducted to each of the saw-cuts. The form of the channels is shown in Fig. 3766, which represents four channels cut across the middle of their length, to show their section, from which it will be seen that the channels are made as a series of Gothic-

shaped tunnels, supported only on one side, and open on the other for the admission of the sand; the water flows through these tunnels, and, continually washing against the convex side of the channel, undermines the sand, which falls into the water and is carried down. There is a sand-trough and set of channels on each side of the water-cistern, so that every saw-cut receives two streams of sand and water in the course of its length. The saws having been adjusted to the proper distances for the required slabs, the saw-frame is raised by means of a windlass and the suspended chains attached to the vertical frames, and the block of marble to be sawn is mounted upon a low carriage, and drawn into its position beneath the saws, and adjusted by wedges. The saws are then lowered until they rest upon the block, the counterpoise weights are adjusted, and the mixed sand and water allowed to run upon the saw-blades, which are put in motion by attaching the connecting-rod to the pendulum. The sawing then proceeds mechanically until the block is divided into slabs, the weight of the saw-frame and connecting-rod causing them gradually to descend with the progress of the cutting. To allow the sand and water to flow readily beneath the edges of the saw-blades, it is desirable that the horizontal frame should be slightly lifted at the end of each stroke. This is effected by making the lower edges of the frame, which bear upon the guide-pulleys, straight for nearly the full length of the stroke, but with a short portion at each end made as an inclined plane, which on passing over the guide-pulleys lifts the frame just sufficiently to allow the feed to flow beneath the saws.

3766.



Diamond Stone-Saw.—The carbon, black diamond, or bort (see DIAMOND), inserted in steel blades, has been adapted with much success to stone-sawing. In Young's saw the diamonds are made to act upon the stone in such a manner as to receive the pressure or blow in one direction only. Without this provision it is found by experience that the diamonds become quickly displaced from their sockets. The carbons are inserted in indentations in the blade, and are held by brazing.

The machine (for a description of which see *Scientific American*, xxxii., 68) consists of a sash-frame carried on horizontal slides between the posts, and supported on the nuts of eight screws which may be turned simultaneously by suitable gearing. The frame is reciprocated by a crank and pitman. For depressing the saw when it moves forward and raising it on the return stroke, an eccentric is provided on the crank-pin of the pitman, which through a connecting-rod actuates certain levers and cams, the effect of which is to push down the saw against its own spring at the beginning of the stroke, and so hold it at a given point until the end. The resilience of the metal lifts the blade on its return. The following data of average downward cut per hour in various kinds of stone are given by the manufacturer: Connecticut brown stone, from 2 to 3 ft.; Dorchester (N. B.) do., 2 ft. 6 in. to 3 ft. 6 in.; Amherst (O.) do., 3 ft. 6 in. to 4 ft. 6 in.; Lockport (N. Y.) limestone, 14 to 18 in.; Marblehead (O.) limestone, 2 to 3 ft.; Canaan (Conn.), Westchester (N. Y.), and Lee (Mass.) marbles, 12 to 16 in.; red Scotch granite, 3 in.; hard slate with quartz veins, 2 ft. 6 in. to 4 ft. The kerf made is from $\frac{5}{32}$ to $\frac{3}{16}$ of an inch wide.

SCALES. See BALANCE.

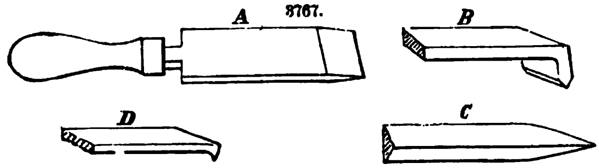
SCARFING. See CARPENTRY.

SCHEELE'S CURVE. See FRICTION.

SCOURING MACHINE. See LEATHER-WORKING MACHINERY.

SCRAPER. A tool employed in the final fitting and adjustment of metal-work requiring to be very true. Its various forms are shown in Fig. 3767, *A*, *B*, *C*, and *D*. That shown at *C* is a three-cornered scraper, made out of a triangular piece of steel, having three sharp edges at its end. It is mainly useful for operating in bores or holes. Those shown at *A*, *B*, and *D* are different forms of what are termed flat scrapers, *D* being the most desirable.

3767.



The proper method of procedure in scraping a flat surface is to first go all over it, leaving the scraper-marks as shown in Fig. 3768. The second time of going over the surface should leave the marks as shown in Fig. 3769. After each scraping the surface-plate is applied and rubbed well over the work to mark it, giving the surface of the plate a barely perceptible coat of marking, and distributing the same evenly all over with the palm of the hand, so as to detect any grit that may chance to have got into the marking. For wiping the surfaces clean a piece of old rag (which is better than either new rag or waste) should be used, and great care should be taken that the surfaces have no dust or grit upon them, or it will scratch the surfaces. The surface-plate is made to mark the work by being rubbed back and forth upon it; or, if the work is small, it may be taken from the vise and rubbed upon the face of the surface-plate. In either case the high spots upon the face of the work will become very dark, or, if the amount of marking applied is barely sufficient to dull the surface of the plate, the marks will be almost black, and will by continuous rubbing upon the plate become bright. Here it may be observed that small work applied to the plate should be rubbed at the corners and toward the outer edges of the plate, so as to keep the wear of the latter as even as possible, since the middle of the surface of the plate generally suffers the most from use, becoming in time hollow. The harder the plate bears upon the work, the darker the spots where it touches will appear, so that the darker the spots the heavier the scraping should be performed. It will be noted that the scraper-marks are much smaller and finer

3768. 3769.

at and during the last scraping; and it may be here remarked that the scrapings are taken very light and in a direction lengthwise of the surface-plate marks during the finishing process. J. R.

SCREW-CUTTING LATHE-TOOLS. See LATHE-TOOLS, SCREW-CUTTING.

SCREW-CUTTING MACHINES. There are two methods of screw-cutting. In the first, the piece to be threaded is held in lathe-centres, and the tools are held and guided independently of their bearing at the cutting edges. This includes all threading processes performed on lathes, whether with a single tool or by dies carried positively by slide-rests, or by milling. In the first instance it is termed chasing. This method will be found fully treated under LATHES and LATHE-TOOLS.

The second method is performed in special machines commonly known as bolt-cutters, bolt-threaders, or screwing machines; and to these the present article relates. They consist essentially of devices for rotating either the work or the cutting die, and for holding and presenting the former. Of these, Mr. J. Richards distinguishes four classes, namely: 1. Machines with running dies mounted in what is called the head; 2. Machines with fixed dies, in which motion is given to the rod or blank to be threaded; 3. Machines with expanding dies, which open and release the screw when finished without running back; and 4. Machines with solid dies, in which the screws have to be withdrawn by changing the motion of the driving gearing.

In this country the principal form of machine combines the advantages of the first and third classes. The advantage of running dies lies in the fact that the blanks may be clamped while the machine is in motion; and as the blank does not revolve, it may, when long, be supported in any temporary manner. The dies may also be arranged to be opened and closed by the driving power, so that no stopping of the machine is necessary.

The Sellers Bolt- and Nut-Screwing Machine, Figs. 3770 to 3774, is an example of the above-described class. In this, the motion of the dies is always in one direction, and the bolt is cut at one operation; the dies open while they are revolving, and do not run backward. The construction of the essential portions of the machine will be understood from Figs. 3771 to 3774. The three dies *a* are held in radial slots cut in a steel die-holder *A*, Figs. 3773 and 3774, attached to the internal sleeve *B*; these dies abut against the three cams *b*, fastened to the external sleeve *B'*. Covering the die-box formed by *A* and *b* is a plate *C*, Fig. 3774, secured by screws to *b*, and carrying upon its inner surface certain cams *c*, which work in corresponding grooves in the sides of the dies. The function of the cams *b* is to close the dies on the bolt being cut, that of the cams *c* (which are respectively concentric with the others) to open them. Now, it evidently follows that the cams *b* may be adjusted in such a manner as to bring the dies nearer to or farther from the centre of the die-box; that is, the dies may be adjusted for size, to compensate for wear, etc.

The operation of this portion of the machine may be briefly described as follows: Upon the sleeve *B*, Fig. 3772, are carried two arms *D D'*, Fig. 3771, terminating in ends with curved slots; on the end *D* is carried a steel pointer *d*. Upon *B* is fitted a toothed wheel secured from motion by two bolts; while keyed to the sleeve *B'* is a similar but somewhat smaller wheel, having on its hub a projection *E'*, engaging with a corresponding segmental projection *E* on the hub of the larger wheel. These

wheels are driven by two pinions $F F'$ on the pulley-shaft, of which the former is keyed fast, while the latter runs loose. F' terminates at one end in a friction-clutch fitting into a recess in the leg of the machine, while at its other end it is provided with a leather disk forming, when brought against F, a sufficiently strong friction connection between the two pinions. $F F'$ are held together by the spiral spring I, adjustable by the loose collar K; while the taper clutch on F' is put in place by the counterweight L. But L is movable by the hand-lever, and a suitable automatic catch H sustains

3771.

3772.

the weight and permits the spring I to operate and F to drive F'; this it continues to do until the projections E and E' strike, when the two sleeves continue to rotate in the bearing B' with the velocity of M, the more slowly moving of the two wheels, while the friction between F and F' tends to keep the clutches on m and m' together and the dies in position. Releasing the latch H enables the weight L to operate, throws the clutch in gear, stops F', and enables F and M to run ahead, and in so doing to change the position of the two sets of cams in regard to the die-holder, relaxing the pres-

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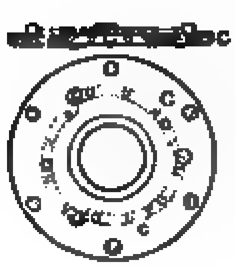


sure on b, and enabling c to open the dies. They continue to open until E and E' touch their opposite faces, and then remain open until the bolt is withdrawn and the dies are closed by a movement of the hand-lever, latching it fast. The spring then again operates, and the dies close. The dies are opened automatically by the bolt striking an adjustable rod O, which moves the lever P and disengages the latch. P and its stand R are hollow, and permit the introduction of oil by a pump into the sleeve B at Q. It will be seen at once that a movement of the index arms $D D'$ on M (which

is graduated) will change the position of the die-box with reference to the clutches E and E', and hence alter the depth to which the dies will cut. For nut-tapping, the holder for the tap is secured from motion by one blank die, which acts as a key, the holder being held in the position occupied by the dies used for bolt-cutting, the latter being removed for the admission of the tap-holder.

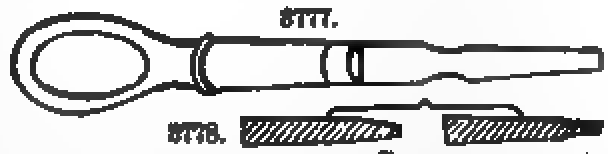
3776.

The Schlenker Revolving-Die Bolt-Cutter, Fig. 3775, manufactured by the Howard Iron Works of Buffalo, N. Y., belongs to the same class. The dies are opened automatically when the desired length of thread has been cut on the bolt, and are closed by the hand-lever shown on the left of the machine. The claimed capacity of the apparatus is from 3,000 to 3,500 five-eighths bolts, with 1¼ inch of thread, per day.

The Wiley & Russell Bolt-Cutter and Nut-Tapper, made by the Wiley & Russell Manufacturing Company of Greenfield, Mass., is represented in Fig. 3776. In this machine the die is stationary and the blank is caused to revolve. Various sizes of dies are placed in the head, which may be rotated so as to present any desired die to the blank. An improved form of adjustable die is used in this machine.

SCREW-DRIVER. An implement used for inserting or withdrawing screws. Fig. 3777 is an ordinary screw-driver, the point of which should be shaped as shown at A in Fig. 3778, and not as shown at B, as is usually the case; because if the part entering the screw-head is tapered, it not only raises a burr on the screw-head, but it is liable to slip out, even from a screw that drives easily, and much more from one that drives hard. To grind it to the shape shown at A, it should be ground on that side of the stone running toward the operator, the length of the screw-driver being at a right angle to the plane of the stone, and the handle held in one hand, while the driving end is held in the other, which should be supported by the grindstone rest. If the stone is a small one, the screw-driver, while being ground in this position, should be moved a little, so that first one corner and then the other will approach the stone, so as to prevent the grinding from being hollow, which would weaken the screw-driver point by thinning it in the middle. Screw-drivers should be made of cast steel, and tempered at the point to a blue color. The advantage gained by using long screw-drivers is due to the leverage obtained by the augmented length of handle. Screw-drivers are often efficiently used when inserted in an ordinary brace. J. R.

3777.



3778. B A

SCREW-FORGING. See FORGING MACHINES.

SCREW-GILL. See FLAX, MACHINERY FOR PREPARATION, etc.

SCREW-MAKING MACHINES. In these machines, as generally built, the rods of iron pass through the hollow cone-spindle, and are operated upon by a series of tools in a revolving head, which cuts the screws to the required size and shape, and cuts the threads thereon. Mechanical devices are provided whereby the rods of iron may be passed through the cone-spindle to the distance required to make a screw while the machine is in full motion. The operator first adjusts the tool in the revolving head, and then, by successive movements back and forth of levers or handles, the machine performs all the operations necessary to make a screw, with the exception of forming the nick in the head.

Figs. 3779 to 3783 represent a screw-making machine manufactured by Messrs. Brown & Sharpe of Providence, R. I. A is the bed of the machine, having the standards for the cone-spindle bearings cast solid thereon. B is the hollow cone-spindle. C is a sliding head adjustable on the bed A, and carrying the slide D, which is operated by lateral movements of the lever E, which on the forward stroke moves the revolving head F up to the work and along it to the required distance, and on the backward stroke moves F laterally back and causes it to turn one-sixth of a revolution. F is provided with holes to receive tools or tool-holding devices, and is arranged to bring the tools held therein in line with the work, ready to operate upon it when D is advanced. In one of the six tool-holes is placed a blank, so adjusted that when it stands opposite or in a line with the axis of the cone-spindle, and the rod of iron is pushed through the cone-spindle until it meets the blank, it will project the proper distance from the cone-spindle to form a screw of the required length without leaving any waste metal. In the next hole is the first tool for operating upon the end of the bar of iron which is to form the screw, and so on with the five successive tools, or such number of them as may be required. G is a lever for operating the slide-rest shown, which carries tools for cutting off the

screws from the rod, and chamfering the ends when required. The slide-rest is duplex, carrying two tools, one on each side of the work, one operated by depressing and one by elevating the lever *K*.

The details of the cone-spindle and patented work-holding devices are shown in Figs. 3780 and 3781, of which the former is a sectional side elevation, and the latter an end elevation. The driving cone-pulley is fast upon the outer cone-spindle, which carries the work-holding chuck and dies, the dies sliding laterally. There is an inner spindle whose end bears when operated forward (to the

3779.

right) against the dies which are contained in the chuck, and close upon the work when forced forward, while opening to release it when pulled backward. A nut affords journal-bearing to the tail end of the spindle. A screw is provided in one piece with the four stationary handle-pieces *O*, which remain stationary while the inner spindle revolves, there being a device for permitting said spindle to revolve, though detained in the hub of the handles. By pulling one of the handles *O* forward, the journal-bearing screw passes up the nut and forces forward the inner spindle, causing its collar to

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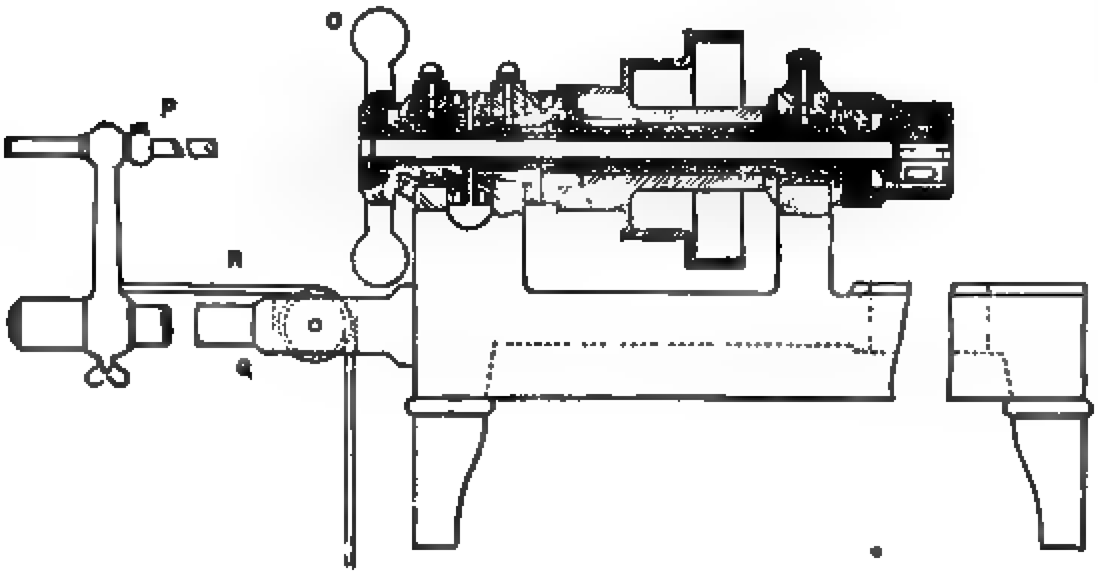

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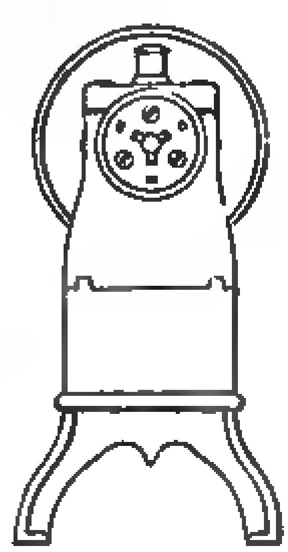
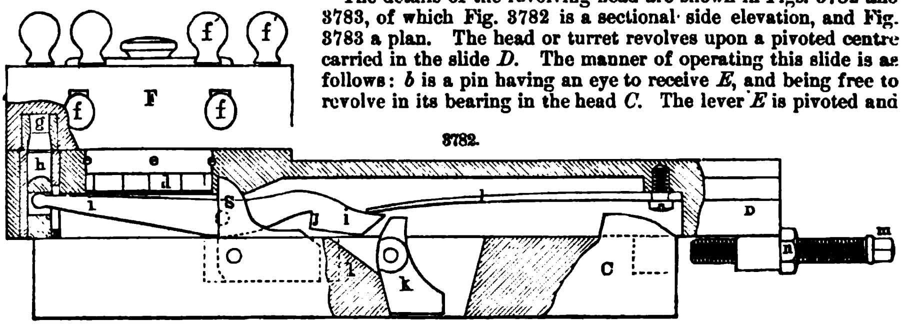


force the work-holding dies to close upon and hold the work, while a converse movement of *O* releases it, as is necessary to put the rod of iron forward through the inner spindle for each screw. The operation is to pass the rod of iron through until it touches the stop in the revolving head, and pull forward the handle *O*. To avoid the necessity of having to push the bar through the spindle for each successive screw, the gauge-rod *P* is provided. This is simply a rod sliding on the feed-bar or arm *Q*, and held against the end of the iron rod by means of the cord *R*, to the end of which a weight is

attached; hence, so soon as the work is released from the dies, the rod *P* pushes it forward and against the adjusted stop in the revolving head.

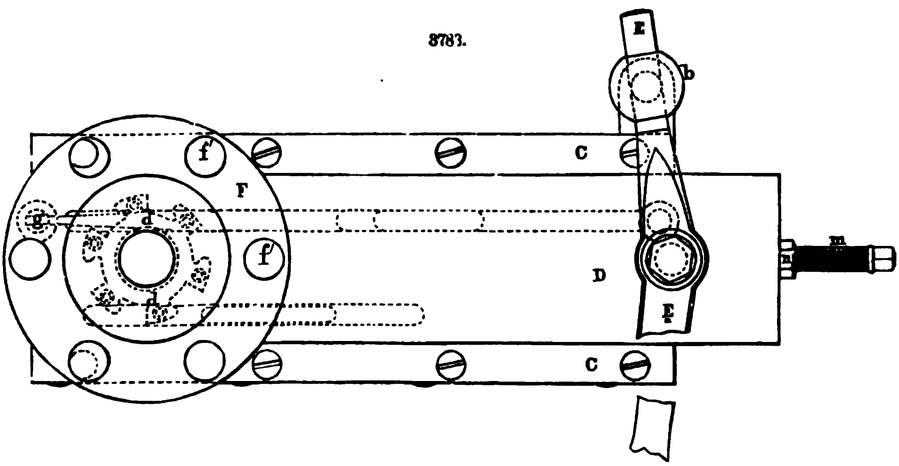
The details of the revolving head are shown in Figs. 3782 and 3783, of which Fig. 3782 is a sectional side elevation, and Fig. 3783 a plan. The head or turret revolves upon a pivoted centre carried in the slide *D*. The manner of operating this slide is as follows: *b* is a pin having an eye to receive *E*, and being free to revolve in its bearing in the head *C*. The lever *E* is pivoted and

3782.



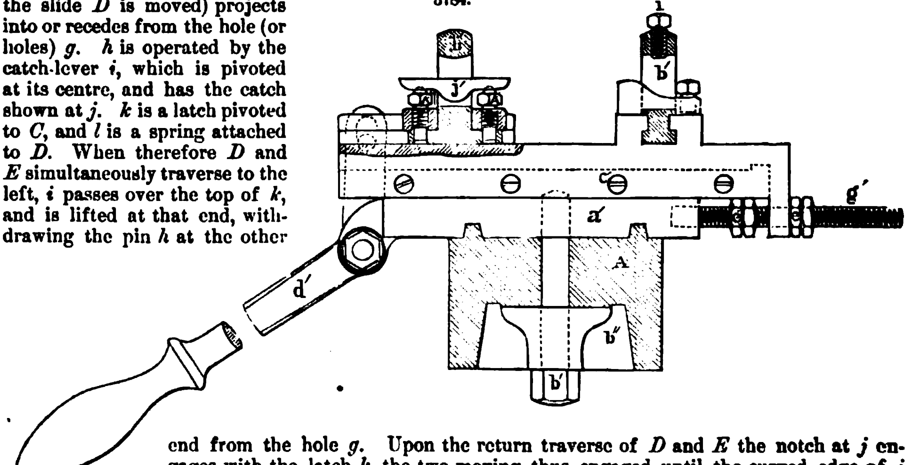
moves the slide *D*. In Fig. 3782 the bottom of the turret is shown, provided with a device having six projecting pieces or lugs. As this is fitted into *D* at *e*, and as *S* is a stationary catch, each time the

3783.



lever *E* is operated backward the edge of *S*, meeting one of the lugs *d*, causes the head *F* to revolve. The amount of its revolution is governed as follows: In *F* are provided the six holes denoted by *g*. *h* is a pin, which alternately (as the slide *D* is moved) projects into or recedes from the hole (or holes) *g*. *h* is operated by the catch-lever *i*, which is pivoted at its centre, and has the catch shown at *j*. *k* is a latch pivoted to *C*, and *l* is a spring attached to *D*. When therefore *D* and *E* simultaneously traverse to the left, *i* passes over the top of *k*, and is lifted at that end, withdrawing the pin *h* at the other

3784.



end from the hole *g*. Upon the return traverse of *D* and *E* the notch at *j* engages with the latch *k*, the two moving thus engaged until the curved edge of *i* abuts against *C*, when *i* gradually releases itself from *k*; and when the pin *h* comes opposite to the hole *g*, it is projected therein by the spring *l*. Thus by operating *D* the turret is revolved and locked in position. The holes *g* are so arranged that each may lock with the pin *h*

when the corresponding tool-hole *f* is exactly in its proper position relative to the cone-spindle. The holes to receive the pin *h*, as well as that in which it operates, are lined with hardened steel bushes to prevent wear. *f' f'* are screws to fasten the tools or tool-holders. To adjust the forward movement of *D*, the set-screw and jamb-nut *m n* are provided, the adjustment being made so that when *D* has traversed forward the requisite distance the end of the screw *m* will strike the end of *C* and act as a stop. The tools in *F* are so arranged as to have traversed along the work to the required distance when *m* strikes *C*.

The details of the slide-rest are shown in Fig. 3784. *A* is the bed of the machine. *a'* is a carriage adjustable along *A*, and bolted through the bolt and clamp *b' b''*. The cross-slide is operated by the handle *d'*—the amount of its

3786.

motion in or out, and hence the depth of the tool-cut, being determined by the adjustment of the check-nuts *e'* upon the screw *g'*. *h'* is the tool-holder, and *i'* the tool-fastening screw. To regulate the height of the tool an ingenious device is employed. *j'* is a plate whereon the tool rests, and its height is regulated by means of the screws *A' A'*. It is obvious that the tools are fed to their cuts by means of the lever *d'*.

Screw-Slotting Machine.—Fig. 3785 represents a machine for slotting studs and screws, also constructed by the Brown & Sharpe Manufacturing Company. The slot is cut by a rapidly-revolving cutter having a fine pitch of teeth and secured as shown on an arbor, the blank head being held beneath it

Fig. 3786 is an ingenious device for screw-slotting which may be attached to an ordinary hand-lathe.

A single bolt fastens the platform *A* to the bed of the lathe, the long lever projecting in front. An arbor carrying a circular cutter is held in the lathe-centres. The lever is moved horizontally to open the jaws for inserting or removing the screws, and downward to bring the screws to be slotted against the cutter. A stop-screw governs the downward motion, and thus regulates the depth of the slot.

Screw-Finishing and Polishing Machines, manufactured by the above-named firm, are represented in Figs. 3787 and 3788. Fig. 3787 is the finishing machine, which is especially adapted for finishing

the heads of screws, pins, and a variety of similar work. A half-inch hole extends through the spindle, in which self-adjusting chucks are used. These are opened by the knee of the operator without stopping the machine. Fig. 3788 clearly shows the construction of the machine for polishing screws, studs, etc., which are usually finished with oil and emery.

MANUFACTURE OF WOOD-SCREWS.—The processes and machinery employed in the production of wood-screws (so named from the use for which they are designed, not the material of which they are made), though varying somewhat in detail in different countries and with different makers, are necessarily always the same in general principle; so that the following brief description of their manufacture, as conducted by one of the largest makers in the world, may fairly be considered as illustrating the general method employed, and presenting all the recent and more important improvements in this branch of industry.

As a rule, the iron for the manufacture of screws is purchased in the form of long rolled rods, varying from three-sixteenths to one-half inch in diameter, and weighing from 20 to 50 lbs., coiled into hanks or skeins about 2 ft. in diameter, and bound into bundles of from 200 to 300 lbs. Other material than iron, such as copper, brass, and other composition, is generally bought in the form of finished wire of the size desired.

The first operation is pointing one end of each of these hanks of iron, for the purpose of introducing it into the plate in the process of drawing into wire. This pointing is done in a special machine, by forcing the end of the rod into a tapering hole formed by two revolving dies striking rigidly together at a rate of several hundred blows per minute, thus forming cold, and in a moment's time, a much better point than that previously obtained by the slow laborious process of heating and drawing at the forge. Then follows a thorough cleaning by subjecting the rods to a hot bath of sulphuric acid and water, in proportions varying greatly, according to the condition of the iron. Strong metallic reels, laden with hanks of rods, are lowered, by means of a kind of crane operated by power, into large tubs of the boiling liquor, where they are allowed to remain till the action of the acid has removed all scale and rust, when they are lifted out and thoroughly rinsed by submerging in a tank of clean cold water. A coating of lime or the gluten obtained from rye-meal is then carefully applied to every portion of the hanks, to prevent scratching and excessive heating of the wire-plate in drawing, after which the load of rods is lowered on to a truck, the reel tripped and withdrawn, and the rods drawn away to dry preparatory to being brought to the wire-block—a powerful iron drum, mounted upon, and connecting by a clutch with, the upper end of an upright revolving shaft. It is upon this machine that the rods are converted into wire. The pointed end of the rod is passed through a hole carefully reamed to the desired size in a steel or chilled-iron plate securely fastened to the frame of the machine, and the projecting end seized by a strong pair of pincers, which are slowly but firmly drawn back by power, pulling the end of the wire with them till a piece is obtained sufficiently long to fasten to the block, when the latter, by winding the wire about its circumference as it revolves, continues the process of drawing till the whole hank has passed through the plate, when a device designed especially for this purpose catches the loose end, and automatically arrests the movement of the whole machine. This automatic stopping of the block occurs not only when a hank is completed, but also if by chance the rod breaks or kinks, or the reel becomes displaced during the process of drawing.

It is at this point that we enter upon screw-making strictly speaking; for the operations described thus far are in every respect similar to those practised by manufacturers of wire for general purposes; but in the next machine, the header, the stock undergoes a decided change in form, and begins to assume the appearance of a screw. The end of a coil of wire placed on a reel at one end of the machine is passed between a pair of feed-rolls operating upon the wire by friction, and thence through a steel tube and die into the central part of the machine, where the length of wire introduced at each impulse of the feed-rolls is accurately determined by an adjustable gauge. Here this piece is cut off, grasped between two fingers, and carried to the opposite end of the die, where it is pushed back into a hole having its outer extremity chamfered in the form of a screw-head; and the wire's being cut a little longer than the die allows the hammer that now strikes it to force the surplus stock into this countersink, forming the head at a single blow, after which the piece of wire is driven from the die and drops into a box beneath, a screw-blank. In the machine above described the die employed is in a single piece, or, in the phraseology of the manufacturer, solid, and is used for the smaller sizes of screws only, as it has been found more advantageous to head the medium and larger sizes in an open die; i. e., a die drilled and chamfered similarly to that previously described, but divided through the hole into two parts, so that each half presents on one surface the longitudinal section of a screw-blank. The machine in which these dies are used differs but little in principle from that already described, the chief point being the cutting of the wire, here accomplished by a lateral movement of the dies, which themselves carry the piece cut off to a position opposite the hammer, without the assistance of the fingers employed in the solid-die machine.

The blanks, after rattling in saw-dust to remove the oil, are next carried to the shaver and nicker, an ingenious and quite complicated machine, and by far the most varied and interesting in its operation. Surmounting this machine is a large iron hopper containing the blanks to be operated upon, whence they are taken, a few at a time, by a kind of fork with two parallel tines, between which the blanks pass along into receiving slides, where they remain until removed one by one from the extremity of this receiver by a mechanism operating like the thumb and fore-finger of the human hand, which reaches over the machine, seizes a single blank, and introduces it into a pair of revolving jaws immediately below the feeding apparatus. The blank, firmly gripped and rapidly revolved by these jaws, is approached from the front by a steel cutting tool grooved to correspond with the shape of the head desired, which removes the irregularities and surplus stock left by the header, while the blank is maintained in its position by a support brought to bear against it from the opposite side. The jaws, still holding the blank, then pass to the opposite side of the machine, where the blank is

supported on both sides by rests, while its head is automatically held against a small circular saw till the nick is cut to the required depth, when it returns again to its former position, is reshaved to remove the rough edges left by the saw, and finally thrown from the machine into a box by its side. During the processes of shaving and nicking, as also that of threading, described below, a jet of soda-water (a solution consisting principally of sal soda and water, but containing in small quantities several other ingredients, frequently termed "medicine," to prevent rust and insure a bright polish on the finished screw) is maintained upon the blank and tool to prevent the latter's heating.

From the shaver and nicker, with an intermediate cleaning in hot soda-water, the blanks pass to the threader—a machine seeming, to a person unfamiliar with machinery, somewhat similar in external appearance, but in fact performing very different functions. Here we find the same hopper, fork, slides, and general feeding device (which, with slight modifications, is very generally employed on all classes of machinery for operating upon headed blanks), and also the jaws for revolving, and the rest for supporting, the piece to be operated upon. As soon as the blank is fed into the jaws, which in this machine seize the end bearing the head, a small tool with a straight cutting edge approaches the opposite extremity, turns the point, and immediately retires to give place to the chasing tool that passes and repasses over the blank, cutting the thread similarly to an engine-lathe, and varying the number of cuts with the size of the screw and the amount of stock to be removed. This operation completed, the screw is finished, ready for its final cleaning in hot soda-water and sawdust, and packing in paper boxes containing a gross each.

These machines are so arranged as to guard against breakage, whatever occurs, to all appearance almost as effectually as if in possession of reasoning powers. Thus, to prevent the spilling of the blanks, the feeding fork ceases to operate when the receiving slides are filled; and every part of the machine is so arranged as to automatically adjust itself, if by chance a little larger or longer blank finds its way into the jaws; while in case of extreme variation in this respect, or an undue strain upon any portion from any cause whatever, as, for example, the displacement of some of its parts, or even the introduction of some foreign matter, as a screw-blank, between the gears, the whole machine instantly stops, at the same time producing a peculiar sound, which, being easily distinguished above the noise occasioned by the other machinery, serves the purpose of a signal, and continues till the difficulty receives attention. A great amount of time and thought has been devoted to the perfection of the many devices employed on this machinery, and they have all been made the subjects of valuable patents in the United States, Canada, and all the principal countries of Europe.

Though apparently a very simple article, and one in which the field for improvement would seem very limited, yet common wood-screws themselves have been the subject of no small amount of attention from inventors, as is attested by the numerous patents granted in the United States to new or modified forms in their various parts; and the advance from the screw of a century ago is no less than in the many other mechanical products more frequently brought to notice. The screws in use at the commencement of the present century were generally made from rough rods, without a point, and with very imperfect thread cut by hand with a file; and it was not until about 1845 or 1846 that the manufacture of the gimlet-point, which had previously been undertaken and abandoned in Europe, was permanently introduced, though the old blunt screw had for some years previous been threaded by machinery. The improvements that have been devised since that time are very numerous, but few of them have proved of any practical value, and perhaps only one has ever been put into actual use to an extent to warrant special mention in this connection. Briefly described, this improvement, consummated in 1876, consists in a peculiar formation of the core—that part of the threaded portion of the screw included within the spiral formed by the bottom of the thread—by which it is left tapering for a third or half its length from the point where the thread commences to the point of the screw, while at the same time all the threads are cut to an edge, leaving no thick threads near the body, as in the old form; thus securing increased strength at the point receiving the greatest strain, and at the same time avoiding the difficulty of thick threads found in all forms of taper screws previously devised. This screw is estimated to be 50 per cent. stronger than one having a straight core, and has met with such general approval that one of our largest manufacturers, by whom it has been patented, has refitted his factory for the production of this improved pattern only.

SCREW-PILES. See FOUNDATIONS.

SCREW-PRESS. See PRESSES.

SCREW-PROPELLER.* An instrument used for propelling vessels, consisting of a blade wound in the form of a helix or spiral around an axis parallel to the keel of the boat. Its action is similar to that of a free bolt working in a fixed nut. By turning the bolt in the nut it is made to advance in the same; and in the case of the screw-propeller the water represents the nut, and the screw, with the vessel to which it is attached, the bolt. This, however, is not the only theory which has been proposed to explain its action, but some have considered it as a fan which exhausts the water in front of it and throws it out in a current behind; it is thus supposed that the reaction of the water projected behind the propeller moves the ship forward. Although many able engineers have given the subject their deepest consideration and have made it a study of years, it is still an unsolved problem, owing to the difficulty of determining the exact conditions which influence its action.

The paddle-wheel was employed among the ancients, as we find traces of its use by the old Egyptians, the Romans, etc.; but the screw as an instrument of propulsion is of comparatively late date. We find it proposed by Hooke in 1680, Duguet in 1727, Pancton in 1768, Watt in 1780, Bramah in 1784, Fulton in 1794, Cartwright in 1798, and Shorter in 1802; and there are numerous other patents and propositions, of which a very complete review is given in Bourne's "Treatise on the Screw-Propeller." In 1804, two years before Fulton began building the Clermont, Colonel John Stevens of Hoboken, N. J., built and ran a steamboat on the North River, in which he employed a screw-propeller. The

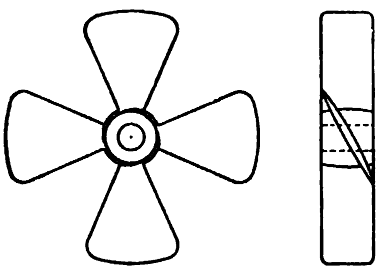
* Prepared by A. Sorge, M. E., under the supervision of Richard H. Buel, C. E.

engine and propeller of this boat are still preserved at the Stevens Institute of Technology. In 1806 he built the Phœnix, which made the trip to Albany from New York in 1807, shortly after Fulton had succeeded in accomplishing the same thing with the Clermont. From this time to 1836 numerous arrangements of screw-propellers were proposed, but no extended use was made of this method of propulsion until Francis Pettit Smith of Hendon, England, and Captain John Ericsson, brought the subject forward, and by their energy and perseverance proved the practical value of screw-propellers for ships. Both obtained patents for the use of the screw in 1836, and from this time forward its application to steamships has steadily increased, until at present there are but few ocean-steamers propelled in any other way; and the same mode of propulsion has frequently been adopted for river-steamers. Since its general adoption numerous modifications have been proposed and patented, but it will suffice if we illustrate the most important kinds that are now employed.

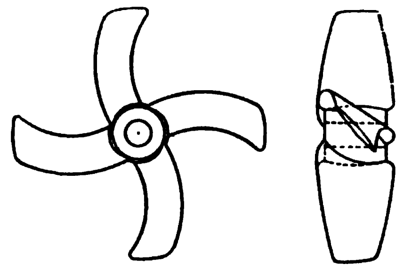
Forms of Screw-Propellers.—In Figs. 3789 to 3796 the acting surfaces of all the various kinds are equal, which gives a very good comparison.

The common screw, Fig. 3789, consists of four blades, whose acting surfaces are portions of helices

3789.



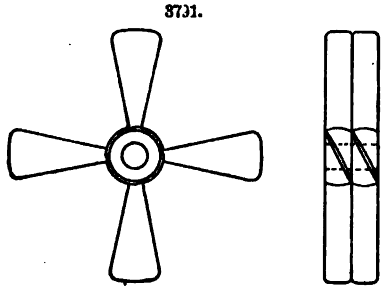
3790.



of true screws. It is so constructed as to revolve in a cylindrical space in the dead-wood of the ship, and has the corners rounded off. It is cast in one piece.

The Hirsch screw, Fig. 3790, is one whose pitch varies both radially and axially. The blades are so shaped that the corner of the acting edge or leading edge first enters the water, and the rest of the

3791.



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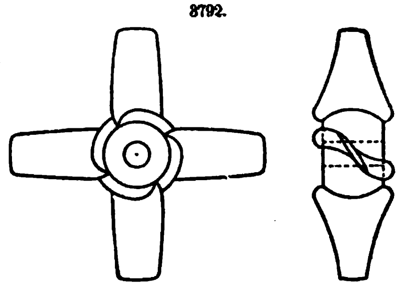
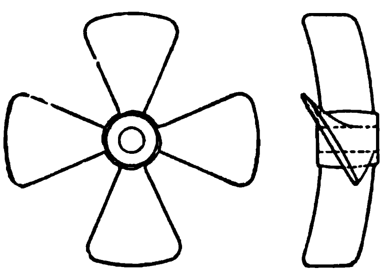


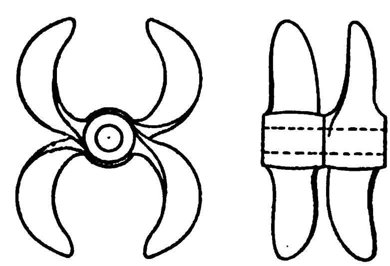
blade follows gradually. The propeller is usually made with the blades separate, and the mode of attaching them to the hub, whereby their positions may be varied, is another of its peculiarities.

The Mangin screw, Fig. 3791, is one of a varying pitch axially; i. e., the advance along the axis varies for different parts of the convolution. Its peculiarity, however, as shown in the engraving, is that it consists of two narrow propellers placed one behind the other.

3793.



3794.



Griffiths' propeller, Fig. 3792, has a spherical hub whose diameter is from one third to one-fourth of the diameter of the screw. The blades vary in width along their length, being about one-third of the diameter of the screw a short distance from the hub, slightly narrower at the hub itself, and about one-ninth of the diameter at the point. The radial section of the blade is slightly curved toward the

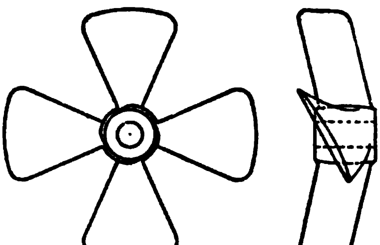
front, and the blades are made separate, being bolted to the hub in such a manner that their positions may be varied and the pitch altered.

Isherwood's screw, Fig. 3793, has its pitch expanding both radially and axially; i. e., the pitch at the circumference is different from that at the hub, and varies also along its length. At the same time this screw is made to overhang the hub.

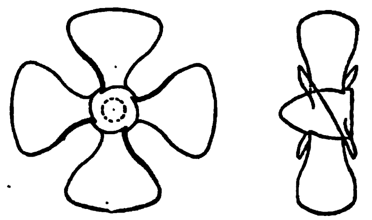
The Collis-Brown screw, Fig. 3794, like the Mangin, consists of two propellers on the same shaft, with blades of the peculiar form shown.

The Ericsson screw, Fig. 3795, is formed from true helices, the same as the common screw already described, the essential difference being that it is made to overhang the hub.

3795.



3796.



The tug-boat propeller, Fig. 3796, has the peculiarity of being formed with blades that are very wide at the circumference and narrow at the hub. The pitch is usually an expanding one.

Designing of Screw-Propellers.—The conditions which must be known in order to lay out a screw-propeller are: its extreme diameter, size and form of hub, the amount of overhang over the hub, whether forward or aft of it, the width of the blade measured along a tangent at its extreme point, or instead of these last two conditions the space in the dead-wood of the ship in which the blade must revolve; also the number of blades, the thickness of the same, and last, but not least, the kind of screw of which the blade forms a part. Indeed, this last condition must be as definitely fixed as the diameter of the screw. In actual use we find generally three kinds of propellers, in which the *generatrix*, or the line which, by its revolution under certain conditions, generates the screw-surface, always passes through the axis of the propeller. This condition is not absolutely necessary, as indeed screw-propellers have been made in which the generatrix crossed the axis; but such cases are rarely found in practice, and their consideration would be foreign to the object of this article. The three kinds or cases which we consider are all made up of straight lines (elements), although curved generatrices might be used, and such have actually been employed in practice. However, for the general purposes of illustration, the cases shown are sufficient; and for those wishing to study the subject more closely and with more minuteness, we can recommend Prof. C. W. MacCord's articles on the screw-propeller contained in the *Scientific American Supplement*, No. 78 to No. 108, in which are given the best methods of laying out propellers, and the subject is treated in a very clear and comprehensive manner. Other good works on the screw-propeller are Burgh's "Modern Screw-Propulsion," Bourne's "Treatise on the Screw-Propeller," and Rankine's "Ship-Building," all of which works have been used in the preparation of this article.

The three cases of screw propellers here illustrated are as follows: Case I., *the true screw;* i. e., the screw in which every equal portion of a revolution of the generatrix corresponds to an equal advance along the axis. In our illustration the generatrix is assumed to be perpendicular to the axis, but it may also be taken inclined to the same at any angle. Case II., *the screw with radially-expanding pitch;* i. e., a certain pitch is given at the hub and another at the circumference of the screw, and a blade has been shown in which all the elements are right lines. Case III., *the screw with axially-expanding pitch;* i. e., the pitch varies continually at each point of the revolution, and according to some fixed law.

CASE I. *Construction of the True Screw.*—Figs. 3797, 3798, and 3799 show the method of laying out a screw-propeller with uniform pitch. Fig. 3797 is an end view, Fig. 3798 a side view, and Fig. 3799 an auxiliary view, for determining the development of the screw-thread. These figures give the diameter of the propeller, $C\,9$; the form and size of the hub; the space in which the propeller is to revolve, represented in the side view by its dotted outline on the plane of the paper, $f'\ a'\ b'\ d'\ e'\ g'$; the pitch, whose development on a tangent plane is represented in the auxiliary view by 0–13; and the normal thickness along the element $i\,9$, represented in the end view by $i\,u\,v\,w\,9$. In order to lay out the pitch-line developed on a tangent-plane, we draw a vertical line through the point 0 in the auxiliary view, and lay off on it with any convenient scale the length of the circumference of a circle whose radius is $C\,9$. At the point thus found we draw a perpendicular equal to the pitch of the thread, and join this latter point with 0. The line thus found represents the development of the thread of a screw of the required pitch and diameter on a tangent-plane. We now draw, with C as a centre and $C\,9$ as a radius, the circle or portions thereof representing the end view of a cylinder on whose surface the whole helix would lie were the space limited in the dead-wood a true cylinder without rounded corners. Lay off on this circle the aliquot parts 1–2, 2–3, 3–4, etc., and draw radii at the various points. These radii will represent the end views of the generatrix in its various positions. It must here be stated that we have assumed $C\,9$ to represent the element in the end view which is in a plane parallel to the paper in the side view, and passes through the point 9′, bisecting the hub at $i''\,i'$. Starting with 9′ in the side view, we lay off on either side of it the parts 9′–8′, 8–7′, 9′–d',

d'–11′, etc., equivalent parts of the pitch, corresponding to the same parts of the circle in the end view. Evidently the verticals drawn through the points 9′, 8′, d', 11′, etc., represent the positions of the generatrix in its progress, if revolved into the plane parallel to the paper. Now $f'\ a'\ b'\ d'\ e'\ g'$ represents the corresponding revolved portions of the blade; hence the intersections of this curve with the verticals give the various points in the outline of the blade which lie on these elements.

3737. 3738.

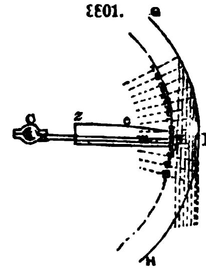
In order to find the true positions of these points, we proceed as follows: Let us take the point a' and try to find its true position in the end view and side view. a' being the position revolved into a plane parallel to $9'\ i''\ i'$, its position if revolved in the end view will be somewhere in $C\,9$. We therefore project a' on $C\,9$ by drawing the indicated horizontal, and thus find the required position n. In its true position, however, a' lies on the element $0\,C$; so we take the radius $C\,n$ and describe the arc $n\,a$, intersecting $0\,C$ in a, which will be its true position, and which we project back to the corresponding element in the side view, by drawing the indicated horizontal line, thus finding a''. In a similar manner the various points of $f'\ a'\ b'\ d'\ e'\ g'$ are projected upon $C\,9$, and are then revolved and projected back again. Thus we find the true outline of the blade in the side and end views. We must now find the intersection of this surface with the hub. This is done in a similar manner to the determination of the point a. Each point of this intersection will lie on the surface of the hub, and their revolved positions will therefore be situated on the outline of the hub shown in the side view. Thus j' represents the revolved position of one point of the intersection lying on the element through c'. This point is projected on the corresponding revolved position of the element in the end view $C\,9$, and is revolved to its true position and then projected back. This operation has not been shown in the same blade, but in the blade to the right of it, merely to avoid confusion of lines. The lines representing the operation of projecting from the side view to the end view are dotted lines, while those showing the reverse operation are broken lines.

We have now defined the acting surface of our blade in the end view and side view. Four blades being required in this case, we draw these four in their respective positions in the end view (as shown), the views being the same for all four in this case. We now project the various points of the outline to the corresponding elements in the side view, and thereby we get a complete side view of all four acting surfaces of the blades, as shown. The point to which we now direct our attention is to show the back of the blade. For this purpose we lay out in the end view the curve $u\ v\ w$ 9, which represents the normal thickness of the blade at the various points of the element, supposing the normals to be revolved into the plane of the paper. We will call this the conventional section, for it is not a true section. In order to show the back of the blade, we intersect the propeller by means of cylinders whose axes coincide with the axis of the propeller. First, however, we find the shape of the blade at the hub. We have already determined the shape of the intersection of the acting surface $k'\ i'\ m'$. At i'' we suppose a tangent drawn to this curve, and erect upon it a normal (perpendicular) $i''\ u'$ equal to $i\,u$. This gives us one point of the required section. For the other points it is necessary that we assume them, as a theoretical determination would be too laborious and complicated a process for the drawing room. We therefore lay out the curve $k'\ u'\ m'$, using for a guide previous constructions of this kind which have proved successful. This section alone is not sufficient, so we determine the intersections of several cylinders of various diameters with the propeller. For our purpose one other cylinder is sufficient. Let us assume one having a radius $C\,s$. Draw the arc $E\,F$ in the end view, representing a portion of the trace of this cylinder. Where this trace intersects the various elements draw horizontal lines to the side view, and find the intersections with the corresponding elements in that view. Thus t is projected to t', z to z', etc. This intersection will be a helix, to which a normal is again drawn at i'', namely, $i''\ v'$, equal to $s\,v$, and then the curve $y'\ c'\ v'$ is assumed. In the side view the various sections are indicated by the shaded parts. In order to determine whether these sections are correct ones, we suppose a plane perpendicular to the axis to cut the propeller, and we find whether the section given in this manner is smooth. The

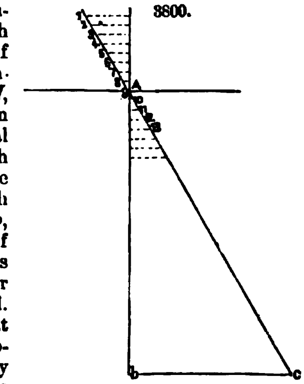
operation of doing this is shown in Case III. Evidently the outline of the back seen in the side view will be tangent to all these sections, and it is only necessary to draw such a curve as seen in the side view and project it back to the end view by drawing verticals from the various points of tangency of the outline with the sections to the corresponding arcs representing the cylinders. To find the intersection of the back of the blade with the hub in the end view, we project the various points in the elements on the side view to the corresponding elements in the end view. These various intersections and traces are now also laid off at each blade, and the drawing of our propeller is finished.

Pattern making.—After the drawing has been made it goes to the pattern-maker, who does the preparatory work for the moulder. In some cases a complete pattern is made of the propeller, and this is then moulded in sand in the usual manner. But generally the blade is "struck" up in loam; that is, a board is guided in such a manner that it produces the required surface. The arrangement employed at the Delamater Iron Works, New York, is sketched in Figs. 3800, 3801, and 3802. Since our acting surface is made up of straight-line elements revolving around an axis and advancing on it simultaneously, it is evident that we can produce the same surface in loam by moving a board having a straight edge in the same manner along a guide-curve which corresponds to the outer helix of the blade. It is the pattern-maker's work to lay out the sweep or straight board and the curved guide-boards necessary to the moulder. He proceeds in the following manner: Draw any vertical line *A b*, Fig. 3800, equal to the circumference (or a certain part thereof) of the required circle of the propeller, and at *b* draw the perpendicular *b C* equal to the pitch (or the corresponding part of it); join *C* with *A*, and this is the developed helix. Let *A* represent the element *C h*, Fig. 3801, and with *C* as a centre strike an arc of a circle with *C W* as a radius; this represents the actual limit of the blade. In order to make the form of the back and of the acting surface fit together, there must be a certain bearing surface outside of the blade. Take, therefore, a radius of say six inches additional length, as *W h*, and strike the arc *G H;* this will represent the end view of the guide-curve. Divide this arc of 1, 2–13 into certain aliquot parts of the circumference, and lay off on either side the corresponding parts of the developed circle. Through the various points in the circle draw radii intersecting the arc *W* in corresponding points, and draw horizontal lines through the points *A b* (Fig. 3800) produced, intersecting the pitch-line *A C* produced in the points 1, 2, 3, etc. The horizontal distances of these points of *A C* from *A b* will be the heights respectively above and below the element *A* of the various elements 1, 2, 3, etc. Through the various points of intersection of the radii with *G H* drop perpendiculars to the side view. The point *h*, Fig. 3801, corresponds to *A*, and is assumed in the side view and a horizontal element *g h* drawn through it. The vertical height of *h* above the base-line being given, the pattern-maker sets his boards (which we assume to have the width of an aliquot part of the circumference) around the circle *G H*, Fig. 3801. The joints are then shown by the dotted vertical lines in the side view. At each joint he subtracts or adds the corresponding horizontal length of the point on *A C* from *A b*, Fig. 3800, from the height of *h* above the base, according as these lengths lie to the left or to the right of *A b* produced. Having thus fixed the points at the joints of the boards, he proceeds to cut off the unnecessary wood until a regular curve is formed corresponding to the one shown in the side view. This curve he produces somewhat beyond the ends of the blade, so as to give a bearing surface for the upper and lower forms. A band of sheet metal is next bent around the guide-curve both inside and outside, thus securing its edges from damage by being handled roughly. The shape of the "sweep" is too clear from the sketch, Fig. 3802, to need explanation. In order to limit the blade, a curve of wood may be constructed, having the end view of the blade as a base, and the various heights of the elements perpendicular to it at the corresponding points; or a sweep may be made having the form of the space in which the blade is to turn, and by revolving this around the same axis the blade will be limited.

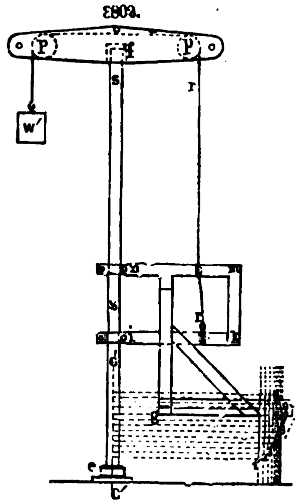
3801.



3800.



3802.



Moulding.—In moulding, the arrangement sketched in Fig. 3802, and partly in Fig. 3801, is employed. *S S* is a vertical shaft which sets in a step *e*, and has a bracket running from the wall of the building with a bearing which goes round the shaft near its top and holds it vertically in position. A casting *n m k i* is clamped around this shaft so that it can revolve freely. To this casting is bolted the sweep-board *g h*, being adjusted until it is horizontal. On the top of the shaft is placed a cap having two small pulleys *p p* in it, and which can freely revolve on the axis. A rope passes from the casting *n m k i* over these pulleys, and has a counterweight *W'* attached to it, which is nearly

equal to the weight of the casting and sweep-board. In starting, the moulder first adjusts his guide-curve $C h$ to be central with the axis. Next the sweep-board is attached to the casting $n\ m\ k\ i$, and the weight W' is adjusted. Hereupon he screws the curve $h\ c\ w$ on his sweep-board. This curve is a section of a plane $A'\ B'$ through the blade (shown in Fig. 3798). He now proceeds to mould the back of the blade by building up his form roughly at first with brick cemented together by sand. Over this rough form he spreads the loam, and brings it to the required shape by rotating the sweep-board around the shaft. He now finishes up his mould of the back by taking off the curve $h\ c\ w$ and forming the edge around the mould as a true screw. Then he rounds off the corners by hand and lets it dry. After drying, dry sand is put over the mould thus formed, and he operates without the curve $h\ c\ w$, thus producing the form of the acting surface. This he now uses as a pattern. He takes away the sweep-board and proceeds to cover the dry sand with loam; upon this loam he builds the bricks, and thus makes the form of the acting surface of the blade. After it is all built and dried he lifts the top off, the dry sand not adhering to any great extent to the loam, and finishes it up. Each blade is thus moulded separately, a core being placed in the centre for the hub and lifted out, when the whole mould is put together; whereupon it is baked in the oven, and then cast. The old method of moulding was to finish the acting surface first, and then the dry sand was placed upon this and formed, whereupon the back was built up above. This method is still used in many places, but it is much more laborious and requires more skilled moulders than the former method.

CASE II. *The Propeller with Radially-Expanding Pitch.*—Figs. 3803, 3804, and 3805 show the method of laying out a propeller with radially-expanding pitch—i. e., with pitch varying continually from the hub to the periphery of the blade. We have given in this case the diameter of the propeller, the form and dimensions of the hub, the space in which the propeller must revolve, the pitch at the periphery, and the pitch at the greatest diameter of the hub; also the condition that the element through a', Fig. 3803, is to be perpendicular to the axis. This latter condition is necessary in specifying the propeller, as it is evident that if the position of some element is not given, an infinite number of propellers will satisfy all the other conditions. In this case only two blades are required, and we must therefore have three views, a top view, Fig. 3804, an end view, Fig. 3805, and a side view, Fig. 3803. We first draw our centre-line $C\ C'$, and perpendicular to this the centre-line of the top view. Then we construct in the side and top views the form of the hub, and show the corresponding circles around C as a centre in the end view. We next indicate the space in which the propeller is to revolve by the dotted outline in the side view, and then draw the circles $A\ B$ and $E\ F$ and the lines $A'\ B'$, $A''\ B''$, and $E'\ F'$, which represent the cylinders on which the blade has the two given pitches. In the end view we now divide our circle into aliquot parts by the radii $a\ C$, $e\ C$, $f\ C$, etc., and lay off on $A'\ B$ and $A''\ B''$ aliquot parts of the pitch corresponding to the divisions of the circle. The letters in the side view correspond to those in the end view. On $E'\ F'$ we lay off the corresponding parts of the pitch on that cylinder. Then we join the respective points thus found with each other, and these lines indicate the positions of the elements revolved into a plane parallel

to $a\ C$. To find the true form of the blade, we proceed with each intersection of one of the elements with the dotted outline in the manner here indicated. The intersection of the element through i' is projected to the vertical $a\ C$ at the point k; this is revolved to l and projected back to l', where this projecting line intersects the vertical through the original point. In order to find the intersection of this surface with the hub, we prolong the elements in the side view until they intersect the outline of the hub; through these points draw verticals as shown, and proceed in the manner indicated in Case I. We must now also project this curve in the top view. For this purpose proceed with each point as is here indicated for the point l. Revolve l to m around C as a centre, and then draw a vertical line to the top view, finding the point where this intersects the corresponding element in m'; this point m' is now revolved back along $m'\ n'$ until it intersects the vertical through l, which will be the required point n'. We now assume one conventional section along $a\ C$, and by means of it the section at the hub. We now indicate a cylinder by the circular arc $G\ H$ and the line $G'\ H'$, and find its intersection with the blade. Every point in the intersection will lie on this cylinder, and if revolved will reach the point H or will lie in the line $G'\ H'$ in the top view. Since our intersections with elements must also lie in these elements, their revolved positions will be the points at which these revolved elements intersect $G'\ H'$. From the points of intersection of the elements on $G\ H$ draw verticals, and from the corresponding points on $G'\ H'$ horizontals; their points of intersection will be the required points through which a curve is drawn. On this helix (for such it is) we now draw the required section, taking our normal height from the conventional section, and then we show the outline of the back of the blade and its intersection with the hub, as in Case I.

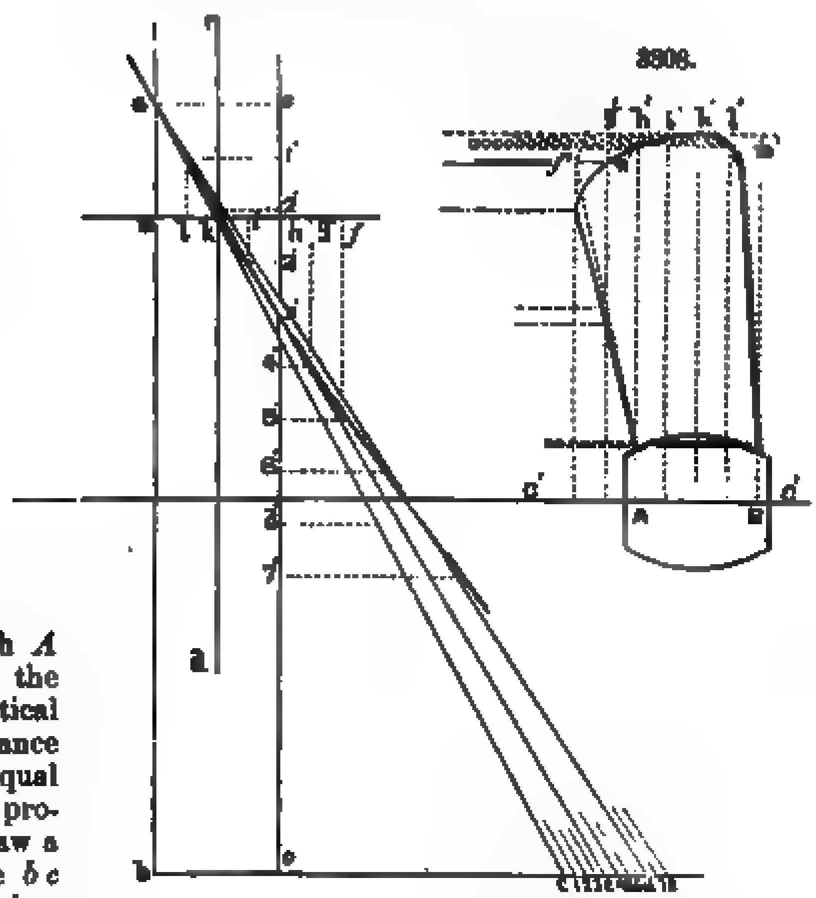
Moulding.—When this blade is to be struck up in loam, two guide-curves must be made, one for the outer helix and one for the helix at the hub. Also the casting holding the sweep-board in Fig. 3802 is made in two separate pieces instead of one as shown in Case I. The lower piece hangs from the upper arm and has the sweep-board attached to it. Instead of a circular hole, through which the axis passes in the lower arm, it has an oblong hole which allows it to adjust itself to the angle which the sweep-board makes, and which varies continually, as is seen in Fig. 3808. In other respects the method of proceeding is the same as in Case I.

CASE III. *The Propeller with Axially-Expanding Pitch.*—The third case which we will consider is the one in which the pitch expands axially; that is, the pitch varies while the element revolves, or, in other words, for the same advance along the axis the element revolves through different angles. This expansion is usually assumed to occur according to the law of falling bodies; if, therefore, we develop this helix on its tangent-plane, we produce a parabola. Only one blade is shown in Figs. 3806 to 3809; the others can be laid out by the general method given under Case I. We have given the diameter of blade, size and form of hub, limiting space (indicated by dotted line in the side view, Fig. 3808), the pitch of the leading edge, and the pitch after having advanced through $A\ B$. We now proceed as follows: In the auxiliary view, Fig. 3809, draw any vertical $a\ b$, and parallel to it draw $c'\ o$ at a distance $a\ c'$ equal to $A\ B$ from it. Lay off $a\ b$ equal to the circumference of the circle of the propeller on any convenient scale, and draw a horizontal line through b. Now make $b\ c$ equal to the entering pitch, and $b\ d$ equal to the pitch after the advance $A\ B$, on the same scale, and $b\ e$ the pitch at the middle point lying halfway between c and d. Draw $a\ c$, $a\ d$, and $a\ e$; where $a\ e$ intersects $c'\ o$ in e' will be one point in the required parabola. Divide $c'\ e'$ into a certain number of equal parts, and draw horizontal lines; then divide $c\ e$ into the same number of parts, and join the points of division with a; their intersections with the horizontals drawn from $c'\ e'$ will be points in the parabola. To the other side of e' lay off parts e'–$4'$, $4'$,–$5'$, etc., equal to those found by dividing $c'\ e'$, and divide $e\ d$ into the same number of

3806.

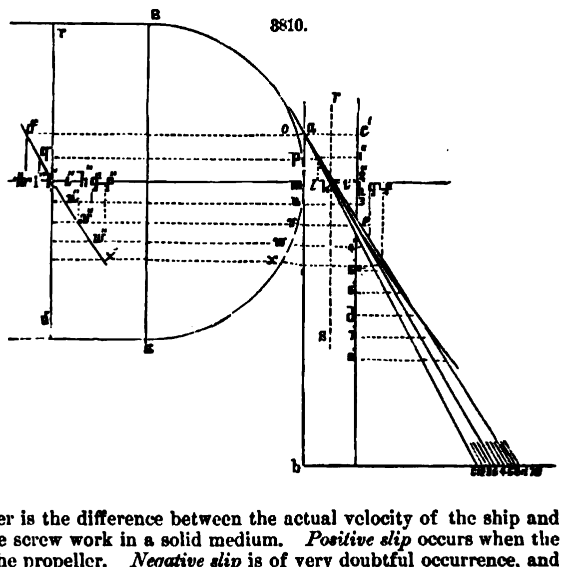
3809.

3808.



parts as its equal $c\,d$, and lay off points 7, 8, etc., to the right. Joining these latter points with a and drawing horizontal lines through 4′, 5′, 6′, etc., the points of intersection of corresponding lines will also lie in the required curve. It remains to wrap the curve thus developed around the cylinder again. Bisect $a\,c'$ and draw the vertical $r\,d$; the point of intersection of this line with the parabola corresponds to $k\,k'$, Figs. 3807 and 3808. To show the method of wrapping the curve around the cylinder again, we will indicate the process with the point g, Fig. 3809. Through k, the point of intersection of the parabola with $r\,d$, draw the horizontal $m\,h\,f$, and lay off from h any distance $h\,g$. In the side view draw a perpendicular to the axis $C'\,C'$ through k', and from its foot lay off a distance equal to $h\,g$, Fig. 3809, and there erect another perpendicular intersecting the dotted outline $m'\,g'$; this perpendicular represents the side view of the element through g'. In order to find the end view of this element, we erect a perpendicular to $m\,k\,f\,a\,g$; then the length of this perpendicular to where it intersects the parabola is the developed length of the arc, which, if wrapped around the cylinder again, would give us the true position of the end of the required element. Thus in the end view draw the tangent $g\,k$ to the circle of the propeller, and lay off the perpendicular distance from g to the parabola on this tangent, equal to $g\,k$ in the end view. Take three-fourths of $g\,k$ for a radius, and the point p thus found for a centre, and strike an arc intersecting the circle of the propeller in n; this is the required point, and a radius drawn from C is the required element. In this manner any number of elements may be found, and then, by projecting the intersections with the dotted outline and revolving and projecting back again, the true views of the blade are found. In the top view the corresponding elements are drawn and the points projected up from the end view. As to the back, the operation is exactly the same as that in Case I., and need therefore not be repeated. There is another operation illustrated here, which was referred to in Cases I. and II.; that is, the process of determining whether our assumed sections at various radial distances from the centre are good or not. For this purpose we suppose the blade to be intersected by a plane perpendicular to the axis and shown in the top view by its trace $J\,K$. We suppose the various sections to have been determined, in this case two besides the one at the hub. The line $J\,K$ intersects the top view of section $E'\,F'$ in w' and v'. These points are projected into the end view by drawing vertical lines through w' and v', and determining the points w and v where they intersect the arc $E\,F$. These two points will be in the required section. Similarly points are determined in $G\,H$ and in any number of sections. If now a curve drawn through all these points is regular without any uneven portions, the sections can be assumed to be good, for there will be no sudden changes in the surface of the back of the blade. Sections like $J\,K$ are made at various points, and our previous work is thus tested.

Moulding.—The method of moulding a propeller of this class is exactly the same as that used in Case I., the only difference occurring in the laying out of the guide-curve, which is illustrated in Fig. 3810. The method depends directly upon the operation of drawing the parabola and wrapping it around the cylinder, which has already been given. In this figure, however, the cylinder $E\,B$ is 12 inches more in diameter than the one in Fig. 3806. The letters correspond to those used in Figs. 3806 to 3809. The parabola is laid out in the same manner; then a circle is drawn tangent to $a\,b$ at m, and with $E\,B$ for a diameter. The various points of intersection of the perpendiculars from $m\,f$ with the curve are then projected on $a\,b$, corresponding to the tangent $f\,k$ in Fig. 3807. They are now wrapped around the circle $B\,E$, and horizontal lines are drawn from the points o, p, m, u, v, etc., thus found. In the side view of the cylinder, $r\,s$ is drawn corresponding to $r\,s$ in the development, and the line $m\,f$ is produced intersecting $r\,s$ in k''. On either side of k'' perpendiculars are erected to $m''\,f''$ at points corresponding to the same letters in the development. The intersections of these perpendiculars with the horizontals already drawn from o, p, m, u, etc., give us the required curve. If now we assume the height of any point as k'', we can easily set our boards around $E\,B$ and mark these heights, then work it into a uniform curve and face it with metallic strips, and we have our guide-curve.


3810.

DEFINITIONS.—The *slip* of a propeller is the difference between the actual velocity of the ship and the velocity which would result did the screw work in a solid medium. *Positive slip* occurs when the speed of the ship is less than that of the propeller. *Negative slip* is of very doubtful occurrence, and is supposed to take place when the ship moves faster than the propeller.

Theoretical Considerations relative to the Screw-Propeller.—The theoretical consideration of the screw as a means of propulsion involves the currents produced by the ship, the friction of the surface of the blades, the position of the propeller, and numerous other conditions, which make this problem one of difficult solution; and up to date no satisfactory conclusions with regard to it have been arrived at. Attempts at a solution of portions of the general problem may be found in the *Journal of the Franklin Institute*, third series, vols. lxvi. and lxxii.

In order to find the size and proportions of a screw required to drive a ship at a certain speed, the usual method is to be guided by previous practice. Bourne, in his "Treatise on the Screw-Propeller," gives a very valuable set of tables for the proportions of various screws. A method which is sometimes used is the following: Find the resistance of the ship by the formula given in the article PADDLE-WHEELS, then multiply this resistance by the speed of the vessel in feet per minute; this will evidently give the useful work. Divide by 33,000, and we have the *effective horse-power*. Assuming the total efficiency of the power exerted through the engine and screw to be 60 per cent., we divide the effective horse-power by 60 and multiply by 100. This gives the indicated horse-power of the engine. The diameter and stroke, etc., are now determined for the engine by the rules applicable to marine engines, as explained under the head of ENGINES, STEAM, MARINE. The pitch is now found to be equal to $\frac{A \times P \times 2s}{R}$, where A = area of piston, P = mean pressure on piston, s = stroke, and R = resistance of the vessel.

Then we have, according to Rankine, the following rule for finding the proper disk area of the screw, that is, the area of the blades: Divide eight-tenths of the pitch by the circumference, and subtract the quotient from 1. The remainder expresses the ratio of the area of an equivalent feathering paddle to that of the screw. The area of the feathering paddle-wheel is found by the rule given under that head. (See PADDLE-WHEELS.) Divide that area by the ratio already found, and the result will be the required effective area of the screw. The screw is made of such a diameter as the draught of the vessel will allow, not permitting the blades to approach the surface nearer than one foot. Bourne gives for a good proportion one square foot of the area described by the extremities of the screw to every 2½ square feet of immersed midship section. The pitch should be equal to or somewhat larger than the diameter of the screw, and should be one-sixth of a complete thread when three blades are used.

Burgh gives for the thickness of the blade at the root (in his work on "Modern Screw-Propulsion"): $\frac{\text{area of blade in feet}}{4 \text{ to } 2}$, the higher constant being for wrought iron or gun-metal and the lower one for cast iron.

However, none of these rules give perfectly reliable results, and it is best to be guided by previous practice, of which Burgh's "Modern Screw-Propulsion" gives good examples.

Practical Considerations as to Use of the Screw-Propeller.—With regard to the manner of holding the screw on the shaft, there are various methods. Usually one or two keys are driven along the shaft, and one through the boss and shaft. When the screw is between the rudder and ship, it usually has a bearing on the rudder-post. When it overhangs, or is outside of the rudder, the shaft passes through an oval hole in the post, and the screw is frequently held on the shaft by a nut on the end of it.

Supposing the screw and paddle-wheel to work with equal efficiency, the former is preferable for ocean travel. In order to work well, the paddle-steamer must always be well trimmed or set plumb in the water; for otherwise unequal strains are produced by one wheel being deep in the water and the other being very nearly or completely out of the water. In the case of the screw the position of the vessel does not materially affect the working of the propeller. For these reasons a screw-steamer may be full-rigged, and can make use of the full advantage of the wind, while the paddle-steamer cannot have any other than light rigging. However, the lighter rigging also decreases the resistance to the progress of the paddle-steamer, which again is partly counterbalanced by the resistance of the paddle-boxes. The heavier rigging retards the screw-steamer when steaming directly against the wind, as the large masts, sparring, ropes, etc., create a great resistance. In case of a direct head wind it is advisable for a screw-steamer to use sail and tack, and she would probably proceed the same distance in the direction of her destination as a paddle-steamer advancing directly; at the same time less fuel would be consumed. A paddle-steamer depends almost entirely upon its engine, while a screw-steamer can use sails in connection with steam. The above shows the advantages of the screw over the paddle-wheel for ocean navigation. When we have smooth water, however (i. e., in rivers and shallow water), the paddle-wheel will retain its place, not needing the deep immersion which is necessary for screws. Another advantage of the screw is the fact that the engine can be made lighter than for the paddle-wheel, on account of more rapid revolution.

A valuable paper on the use and construction of the screw-propeller, by Mr. Arthur J. Macginnis, read before the Institution of Naval Architects, is published in *Engineering*, xxvii., 351. The following table is extracted therefrom:

Table showing Construction of Propellers of Liverpool Steamers.*

NAME OF STEAMER.	Diameter.		Mean Pitch.		Surface.	MATERIAL.		Weight.		CYLINDERS.				Stroke.		Revolutions per Minute.	Speed per Hour, Knots.
						Boss.	Blades.			High-Pressure.		Low-Pressure.					
										No.	Diam.	No.	Diam.				
	Ft.	In.	Ft.	In.	Sq. Ft.			Tons.	Cwt.		In.		In.	Ft.	In.		
Iberia	21	0	26	4	111	Steel.	Steel.	18	1	1	56	2	78	5	0	52	14
City of Berlin.	21	6	31	6	150	Cast iron.	Cast iron.	20	0	1	72	1	120	5	6	56	14¾
Britannic	23	6	30	0	124	Wr'ght iron.	Steel.	21	13	2	48	2	83	5	0	52	15¼
Bothnia	20	10	28	1	118	Cast iron.	Steel.	15	10	1	60	1	104	4	6	52	15¼
Ohio.........	17	0	24	0	...	....	....	......		1	57	1	90	4	0	60	13
Sardinian	20	0	25	6	107	Cast iron.	Steel.	16	0	1	60	1	104	4	0	54	12¼

* All of the ordinary Griffiths pattern, with four blades, and all right-handed except that of the Sardinian.

The writer's conclusion is, that "for propellers of 16 ft. diameter and upward the system of having the boss and four blades separate is the best, the former being made of superior cast iron annealed, care being taken not to have it cored out too much (as this has caused the failure of many); the blades should be of the improved steel recently introduced, and of the Griffiths shape, with a good substantial section, the thickness at the root being from half an inch to five-eighths of an inch for each foot of diameter; about 2 in. in from the tip, the thickness should be about 1 in. or 1¼ in.; the points of the blades should be bent from 2 in. to 3 in. aft of the straight or perpendicular line of medial section, commencing about 2 ft. 6 in. from the tip, the horizontal sections on the back of blade being convex, of increasing radii as they approach the tip, and on the driving or after face slightly convex at the root, gradually decreasing until they become straight. The pitch should not vary more than 2 ft. at the most, and should be fine enough to allow the engines to work at a piston speed of from 500 to 560 ft. per minute.

Experiments on Screw-Propellers.—Numerous experiments have been made to determine the best form of screw for propelling vessels; and although some very conflicting results have been obtained by various experimenters, it seems as though variations in the shape as regards the pitch do not materially affect the efficiency of screws. The following dynamometrical results were obtained by M. Taurines in 1860: 1. The useful effect diminishes as the pitch increases. 2. The useful effect increases with the diameter, and the number of revolutions may be reduced when the diameter increases. 3. The four-bladed screw is always superior to the two-bladed, but this superiority is not sufficient to overcome other advantages of the latter. 4. The fraction of surface may be reduced considerably without much altering the useful effect, but when reduced too much the engine will not work regularly.

Mr. Rennie made a series of experiments in June, 1856, on the relative power exerted by a screw immersed at various depths, and he found that the resistance or thrust of the screw increased very rapidly with its immersion, the number of revolutions being the same, and that the law may be illustrated by a parabola in which the abscissæ are the depths of immersion and the ordinates are the thrusts. According to Chief Engineer B. F. Isherwood's investigations, the variation in efficiency of the screws generally employed did not exceed 7 per cent.; in screws having the same kind and quantity of surface, their propelling efficiency in smooth water is not affected by either the number or the position of their blades; and the absolute slip of screws having the same kind of surface, and differing only in its quantity, is for the same speed of the same vessel in the ratio of the square roots of their surfaces. Numerous other conclusions, all for smooth water, and a valuable series of tables of experiments, are given in the report of the above-named engineer in the *Journal of the Franklin Institute*, 1875. These experiments were also made with reference to the resistance of the hull of a vessel propelled through water at various speeds.

Propellers have been made with the pitch varying in almost every imaginable manner. The blades have been shaped like birds' wings, like fish-tails, etc.; but none of these shapes have proved sufficiently successful to induce engineers to adopt them generally. Screws with four blades have been made so that two of the blades can be folded on the other two, thus facilitating the lifting of the propeller on to the deck of the vessel for repairs, or when sails alone are to be used; such a propeller was patented in England by Mr. Britt in 1853.

At one time a large number of propellers of the navy and also of merchant ships were so arranged that they could be disconnected from the shaft and lifted out of the water; but there are very few of such arrangements used now, because it is more economical to leave a little steam in the engine and revolve the screw. (See *Engineering*, January, 1867.)

In order to prevent propellers from dragging when the ship is proceeding under sail, so-called feathering arrangements have been employed, by means of which the blades are turned on the hub until only the edge cuts the water. Such an arrangement is illustrated and described in *Engineering*, August, 1867.

Screws with hollow blades have also been made, in which water is forced through the shaft into the blades, and out of these; and it is claimed that this materially assists the performance of the propeller.

Some engineers advocate setting the screw at an angle instead of vertical, and state that a gain of power results from the fact that the various blades act upon a more uniformly resisting mass than when vertical, as in that case the resistance to the top blade is only the weight of the water above it.

Twin Screws.—Two screws placed on each side of the stern-post of a vessel are sometimes employed. The advantages claimed for this arrangement are: greater security against total disablement of the propelling apparatus; greater handiness, and the maintenance of manœuvring power in case of serious damage to the rudder or steering gear; and greater facilities for the water-tight subdivision of the engine-room by means of middle-line bulkheads. The disadvantages are: greater liability of damage to the screws when ships are going into or out of docks, coming alongside wharves, or taking the ground; reduced cargo-space, in consequence of a larger engine-room and two shaft-passages being required; necessity for a larger and more expensive engine-room staff, in consequence of the machinery being duplicated; and increase in the weight of the machinery, in proportion to the horse-power developed, as compared with single-screw engines. See paper on "Single and Twin Screws," by Mr. W. H. White, Assistant Constructor R. N., in *Engineering*, xxv., 329. The question, however, seems to be narrowed down to one of relative economy (see *Engineering*, xxvii., 179), which has reached no definite conclusion.

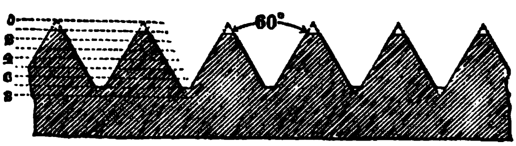
In addition to works already mentioned in this article, the following papers may be consulted: "On the Minimum Area of Blades needed by a Screw-Propeller to form a Complete Column," Cotterill, *Engineering*, xxvii., 385; "On the Action of Screw-Propellers," *Engineer*, xliv., 164–257; "On Feathering Screw-Propellers," *ibid.*, xlvi., 59; "On Propellers in Deep-Draught Ships—Single and Twin Screw," *ibid.*, xlvi., 261. See also Engines, Steam, Marine.

SCREW-THREAD.—*The American or United States standard thread* for ordinary bolt and nut use is based upon an investigation made by Mr. William Sellers, and presented by him to the Franklin Institute in a paper read in April, 1864; and upon a report of a committee of the Franklin Institute thereon, in which report it was recommended that "screw-threads shall be formed with straight sides at an angle to each other of 60°, having a flat surface at the top and bottom equal to one-eighth the pitch (as shown in Fig. 3811). The pitches shall be as follows:

Diameter of Bolt.	No. Threads per Inch.	Diameter of Bolt.	No. Threads per Inch.	Diameter of Bolt.	No. Threads per Inch.	Diameter of Bolt.	No. Threads per Inch.	Diameter of Bolt.	No. Threads per Inch.
$\frac{1}{4}$	20	$\frac{3}{4}$	10	$1\frac{5}{8}$	$5\frac{1}{2}$	3	$3\frac{1}{2}$	$4\frac{3}{4}$	$2\frac{5}{8}$
$\frac{5}{16}$	18	$\frac{7}{8}$	9	$1\frac{3}{4}$	5	$3\frac{1}{4}$	$3\frac{1}{2}$	5	$2\frac{1}{2}$
$\frac{3}{8}$	16	1	8	$1\frac{7}{8}$	5	$3\frac{1}{2}$	$3\frac{1}{4}$	$5\frac{1}{4}$	$2\frac{1}{2}$
$\frac{7}{16}$	14	$1\frac{1}{8}$	7	2	$4\frac{1}{2}$	$3\frac{3}{4}$	3	$5\frac{1}{2}$	$2\frac{3}{8}$
$\frac{1}{2}$	13	$1\frac{1}{4}$	7	$2\frac{1}{4}$	$4\frac{1}{2}$	4	3	$5\frac{3}{4}$	$2\frac{3}{8}$
$\frac{9}{16}$	12	$1\frac{3}{8}$	6	$2\frac{1}{2}$	4	$4\frac{1}{4}$	$2\frac{7}{8}$	6	$2\frac{1}{4}$
$\frac{5}{8}$	11	$1\frac{1}{2}$	6	$2\frac{3}{4}$	4	$4\frac{1}{2}$	$2\frac{3}{4}$		

"The distance between the parallel sides of a bolt-head and the nut, for a rough bolt, shall be equal to one and a half diameter of the bolt plus one-eighth of an inch. The thickness of the head for a rough bolt shall be equal to one-half the distance between its parallel sides. The thickness of the nut shall be equal to the diameter of the bolt. The thickness of the head for a finished bolt shall be equal to the thickness of the nut. The distance between the parallel sides of a bolt-head and nut and the thickness of the nut shall be one-sixteenth of an inch less for finished work than for rough."

3811.



The V-Thread.—The form of the ordinary V-thread is shown in Fig. 3812. The taper of thread is one-sixteenth of an inch per inch of length.

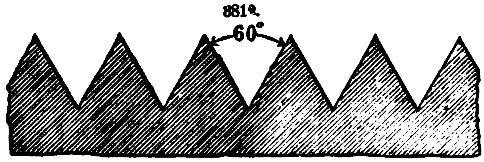
Table showing Number of Threads to an Inch in V-Thread Screws.

Diameter.	Threads.	Diameter.	Threads.	Diameter.	Threads.	Diameter.	Threads.	Diameter.	Threads.
Inches.	No.	Inches.	No.	Inches.	No.	Inches.	No.	Inches.	No.
$\frac{1}{4}$	20	$\frac{7}{8}$	9	$1\frac{3}{4}$	5	$3\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{3}{4}$	$2\frac{3}{4}$
$\frac{5}{16}$	18	1	8	$1\frac{7}{8}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	5	$2\frac{3}{4}$
$\frac{3}{8}$	16	$1\frac{1}{8}$	7	2	$4\frac{1}{2}$	$3\frac{3}{4}$	3	$5\frac{1}{4}$	$2\frac{5}{8}$
$\frac{7}{16}$	14	$1\frac{1}{4}$	7	$2\frac{1}{4}$	4	4	3	$5\frac{1}{2}$	$2\frac{5}{8}$
$\frac{1}{2}$	12	$1\frac{3}{8}$	6	$2\frac{1}{2}$	4	$4\frac{1}{4}$	$2\frac{7}{8}$	$5\frac{3}{4}$	$2\frac{1}{2}$
$\frac{5}{8}$	11	$1\frac{1}{2}$	6	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{7}{8}$	6	$2\frac{1}{2}$
$\frac{3}{4}$	10	$1\frac{5}{8}$	5	3	$3\frac{1}{2}$				

V-Thread in Pipes.

Inside Diameter of Tube, Inches.	No. of Threads per Inch.	Inside Diameter of Tube, Inches.	No. of Threads per Inch.
$\frac{1}{8}$	27	$1\frac{1}{2}$	$11\frac{1}{2}$
$\frac{1}{4}$	18	2	$11\frac{1}{2}$
$\frac{3}{8}$	18	$2\frac{1}{2}$	8
$\frac{1}{2}$	14	3	8
$\frac{3}{4}$	14	$3\frac{1}{2}$	8
1	$11\frac{1}{2}$	4	8
$1\frac{1}{4}$	$11\frac{1}{2}$		

3812.



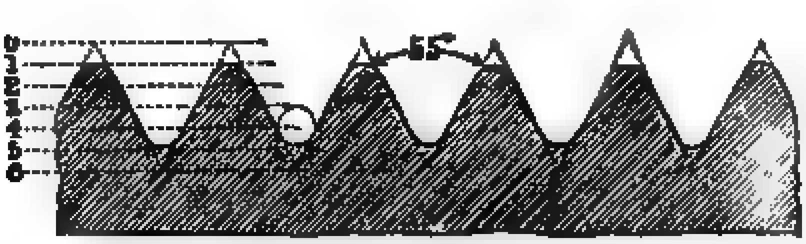
The Whitworth Thread.—The proportions of the Whitworth (English) standard screw-thread are shown in Fig. 3813, and the pitches for the various diameters are given in the following table:

Table showing Number of Threads to an Inch in Whitworth Screws.

Diameter in Inches.	No. of Threads to Inch.	Diameter in Inches.	No. of Threads to Inch.	Diameter in Inches.	No. of Threads to Inch.	Diameter in Inches.	No. of Threads to Inch.
$\frac{3}{16}$	24	1	8	$2\frac{1}{4}$	4	$4\frac{1}{4}$	$2\frac{7}{8}$
$\frac{1}{4}$	20	$1\frac{1}{8}$	7	$2\frac{1}{2}$	4	$4\frac{1}{2}$	$2\frac{7}{8}$
$\frac{5}{16}$	18	$1\frac{1}{4}$	7	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{3}{4}$	$2\frac{3}{4}$
$\frac{3}{8}$	16	$1\frac{3}{8}$	6	3	$3\frac{1}{2}$	5	$2\frac{3}{4}$
$\frac{7}{16}$	14	$1\frac{1}{2}$	6	$3\frac{1}{4}$	$3\frac{1}{4}$	$5\frac{1}{4}$	$2\frac{5}{8}$
$\frac{1}{2}$	12	$1\frac{5}{8}$	5	$3\frac{1}{2}$	$3\frac{1}{4}$	$5\frac{1}{2}$	$2\frac{5}{8}$
$\frac{5}{8}$	11	$1\frac{3}{4}$	5	$3\frac{3}{4}$	3	$5\frac{3}{4}$	$2\frac{1}{2}$
$\frac{3}{4}$	10	$1\frac{7}{8}$	$4\frac{1}{2}$	4	3	6	$2\frac{1}{2}$
$\frac{7}{8}$	9	2	$4\frac{1}{2}$				

Angle of thread = 55°. Depth of threads = pitch of screws. One-sixteenth of depth is rounded off at top and bottom. No. of threads to the inch in square threads = half the number of those in angular threads.

3813.



Whitworth Pipe-Threads.

Diameter of Tube, Inches.	No. of Threads per Inch.	Diameter of Tube, Inches.	No. of Threads per Inch.
1/8	28	1	11
1/4	19	1 1/4	11
3/8	19	1 1/2	11
1/2	14	1 3/4	11
3/4	14	2	11

Threads of Machine Screws.

Table showing Diameter in Inches, Size, and Pitches of Machine Screws.

Diameter.	Wire-Gauge Size.	No. of Threads to Inch.	Diameter.	Wire-Gauge Size.	No. of Threads to Inch.
[illegible]	No. 4	36, 40	[illegible]	No. 14	16, 20, 22
[illegible]	" 6	30, 32, 36, 40	[illegible]	" 16	16, 18, 20, 42
[illegible]	" ..	30, 32, 36	[illegible]	" 18	16, 18, 20
[illegible]	" 8	30, 32	[illegible]	" 20	16, 18, 20
[illegible]	" 10	20, 22, 24	[illegible]	" 24	14, 16, 18
[illegible]	" 12	20, 22, 24			

The various forms of screw-threads are shown in Fig. 3813 A: 1 is the V-thread; 2, the English standard thread; 3, U. S. standard thread; 4, bastard thread; 5, ratchet thread; 6, square thread; and 7, wood-screw thread.

3813 A.

1 2 3 4 5 6 7

SCREW-THREADING TAPS AND DIES. TAPS.—The tap is a tool used to cut threads in holes. It usually consists of a cylindrical piece of steel having at one end a thread of the requisite pitch, and squared at the other extremity to receive a wrench. The threaded end of the tap has longitudinal flutes, so that thread-teeth are thus formed which cut their way into the metal around the orifice.

Construction of Taps.—For executing accurate work, taps of an inch or less in diameter should be made without any clearance in the thread. The thread should be made parallel, and the taper to the taper- and plug-tap should be given as follows: For the taper-tap the thread should be turned off so that the entering end is of the diameter of the bottom of the thread, the taper running straight, and leaving about six full threads at the other end of the tap. By this means, there being no clearance in the thread, the tap will work very steadily, and will tap a hole in which the tap itself will be a neat fit, while all the holes tapped will be of exactly one size. By giving the tap a long taper it will work easier, and is not so apt to tap out of straight; for a tap having no clearance on the thread is very difficult to right if it once gets out of straight after it has entered the hole to more

3814. 3815. 3816.

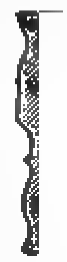
than one-quarter of its length. The plug-tap should be made in like manner, and tapered off for about four threads from the end. A very good plan of easing the friction of the tap is to file a flat place along the tops of the teeth, extending along each tooth nearly to the edges. On taps for ordinary use, however, it is better to give the thread a very small amount of clearance—just enough to relieve the sides and top of the tap from contact—the object being to reduce the friction of the thread in the hole, and not to sharpen the angles forming the cutting edges.

It is not advantageous to taper-taps to reduce the diameter of the threads. The sides of the thread upon a tap have considerable friction upon the metal being cut, especially when the edges of the tap have become somewhat dulled by use. To avoid this friction, an excellent form of tap has been devised by Prof. J. E. Sweet of Cornell University, the principles of the action of which are shown in Figs. 3814 to 3818. The tap is first threaded and tapered in the usual manner, and then heated to change its color, so that the subsequent operations may be better observed. The blank thus prepared, and before being fluted or grooved, is put into the lathe with the foot-stock of the lathe set back—that is, the reverse of the position it occupied when turning the taper on the tap; and then, with a tool somewhat more acute than the one used for cutting the thread, the bottom of the thread is turned away until a new angle is formed on the sides of all threads up to about one diameter of the tap.

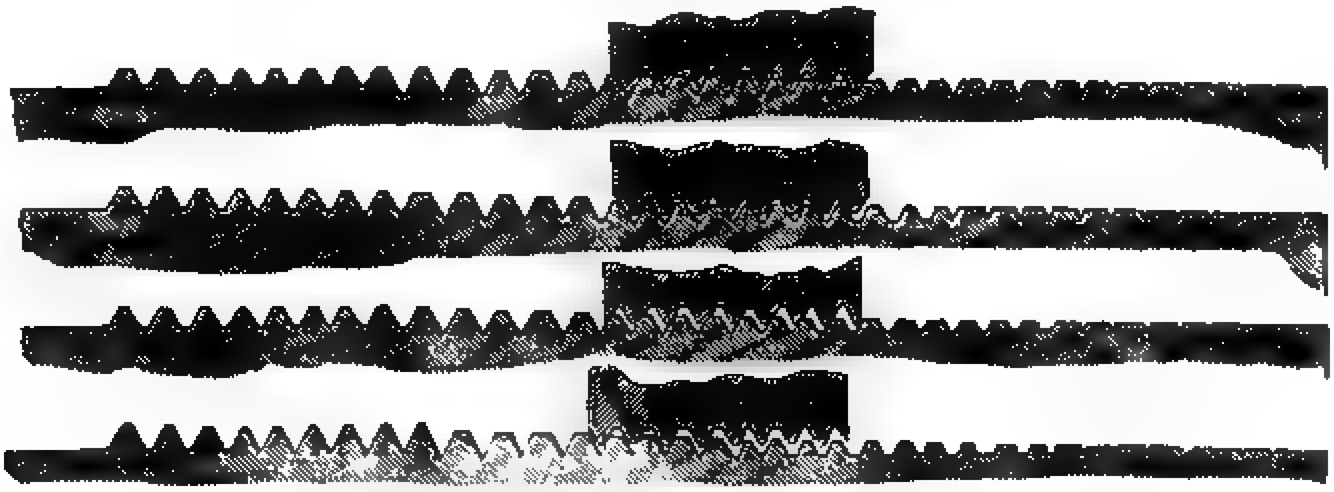
which is left in its original condition to clear out and leave a finished hole. When such a tap is fluted and the outer surface between the flutes filed away, all parts of the tap have a clearance, and, so far as the cutting edges are concerned, a better clearance than if made by either of the old methods.

Another invention by Prof. Sweet, applicable to this or any other style of tap, is shown in Figs. 3817 and 3818. In the ordinary tap, with the taper four or five diameters in length, there are far more cutting edges than are necessary to do the work; and if the taper is made shorter, the difficulty of too little room for chips presents itself. The evil results arising from the extra cutting edges are that, if all cut, then it is cutting the metal uselessly fine—consuming power for nothing; or if some of the cutting edges fail to cut, they burnish down the metal, not only wasting power, but making it all the harder for the following cutters. One plan to avoid this is to file away a portion of the cutting edges; but the method adopted in the University tap is still better. Assume that it is desired to make three following cutters, to remove the stock down to the dotted line in Fig. 3815. Instead of each cutter taking off a layer one-third the thickness and the full width, the first cutter is cut away on each side to about one-third its full width, so that it cuts out the centre to its full depth, as

3817



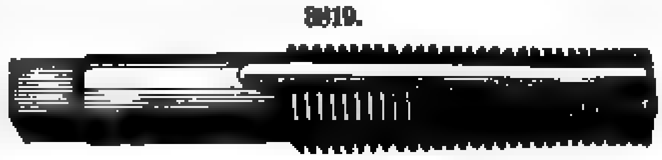
3818.



shown in Fig. 3817, the next cutter cutting out the metal at A, and the next at B. This is accomplished by filing, or in any other way cutting away, the sides of one row of the teeth all the way up; next cutting away the upper sides of the next row and the lower sides of the third, leaving the fourth row (if it be a four-fluted tap) as it is left by the lathe, to insure a uniform pitch and a smooth thread.

Figs. 3819, 3820, and 3821 represent the three ordinary forms of tap. Fig. 3819 is a taper-tap, Fig. 3820 a plug-tap, and Fig. 3821 a bottoming tap. Figs. 3822 and 3823 represent a form of tap which has been successfully used in large tools. The thread is cut in parallel steps, increasing in size toward the shank, the last step (from D to E in Fig. 3822) being the full size. The end of the tap at A being the proper size for the tapping hole, and the flutes not being carried through A, insures that the tap shall not be used in holes too small for the size of the tap, and thus is prevented a great deal of tap breakage. The bottom of the thread of the first parallel step (from A to B) is below the diameter of A, so as to relieve the sides of the thread of friction and cause the tap to enter easily. The first tooth of each step does all the cutting, thus acting as a turning tool, while the step within the work holds the tooth to its cut, as shown in Fig. 3823, in which N represents a nut and T the tap,

3819.



3820.

3821.

3822.

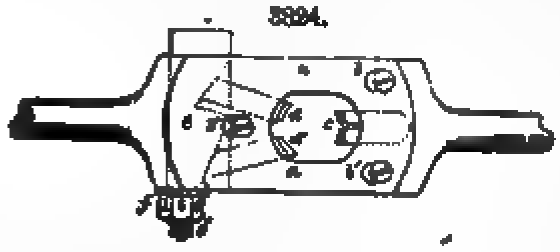
E *D* *C*

both in section. The step C holds the tap to its work, and it is obvious that, as the tooth B enters, it will cut the thread to its own diameter, the rest of the teeth on that step merely following frictionless until the front tooth on the next step takes hold. Thus, to sharpen the tap equal to new, all that is required is to grind away the front tooth on each step, and it becomes practicable to reverse

3823.

the tap a dozen times without softening it at all. As a sample of duty, it may be mentioned that, at the Harris-Corliss Works, a tap of this class, 2¼ in. diameter, with a four-pitch, and 10 in. long, will tap a hole 5 in. deep, passing the tap continuously through without any backing motion, two men performing the duty with a wrench 4 ft. long over all, the work being of cast iron.

3824.



STOCKS AND DIES.—For cutting external threads on rods or bolts, either the screw-plate or stocks and dies are used. The old form of screw-plate was a plate of steel having a tang or handle at one or both ends. Through it were made one or more series of graduated screwed holes, so that, by passing the bolt or pin successively through several, a finished screw was produced. Screw-cutting dies are held in a stock by clamping-screws or other suitable means.

Whitworth's screw-stock is represented in Fig. 3824. The interior of the stock is shown in dotted lines through the top plate *a*, which is fastened by the screws *b b' b'*; *c* is a stationary or fixed die; *d d'* are moving dies simultaneously brought up by a piece *e*, sliding in a recess in the stock, and bearing with a distinct incline, as shown by dotted lines, against the back of each die. The piece *e* terminates with a square-threaded screw *e'*, and is drawn up by a nut *f*, on the outside of the stock. The dies having been cut by a full-sized master-tap, the curve made by their outer edges is that of the blank pin or bolt they are intended to screw. Hence, in starting the thread they bear at all points of the common curve, and the impression made by indentation is an exact copy of the thread of the die. The parts indented serve as a steady guide to the dies in cutting round the blank pin. A groove in the stationary die facilitates the operation. Four cutting edges are brought into action, at points of the circumference nearly equidistant; so that by little more than a quarter turn the thread is completely started round the pin, and the difficulty involved in the operation by the common screw-stock is entirely removed. After the thread is started, the fixed die serves principally as a guide and abutment for the others. The inner edges of the moving dies, which chiefly act in cutting out the metal, are filed to an acute angle. Their action in cutting is similar to that of a chasing tool. The direction of the moving dies is that of two planes meeting beyond the centre of the stock, in a line parallel with the axis of the screw-bolt and considerably distant from it. This direction is determined with reference to the change which takes place in the relative position of the screw-bolt as the thread is cut deeper.

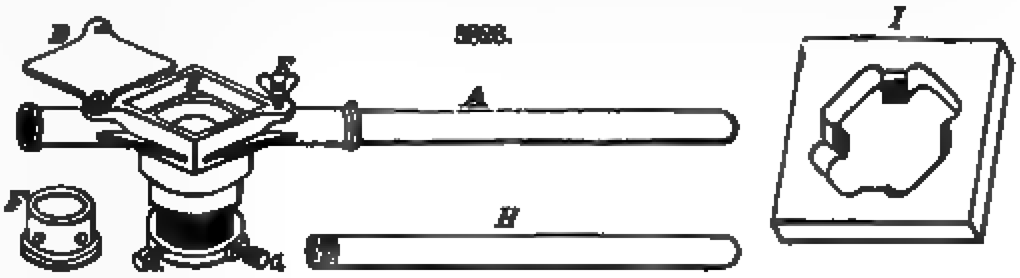
Everett's adjustable screw-cutting stock and dies is represented in Fig. 3825. In this device the dies are set up by a cam-lever, and are closed to the proper diameter when the arm of the cam-lever is coincident with the arm of the stock. By turning the cam-lever half a revolution, the straight side of the lever faces the dies; hence the latter may be instantly removed and others substituted. The dies may be used to cut up and down the bolt; or, after a cut is taken down the bolt, the movable die may be slackened back (by moving the cam-lever), and the stock lifted again to the top of the bolt to take another cut, or to remove it on completion of the thread.

3827.

The Lightning Screw-Plate, manufactured by the Wiley & Russell Manufacturing Company of Greenfield, Mass., is represented in Fig. 3826. The adjustable die is shown separate and apart in Fig. 3827. In Fig. 3826, *A* is the die; *B*, the collet; *D D*, the taper screws regulating the cut; and *E*, a

binding-screw. Another binding-screw, not shown in the cut, opposes the screw E on the other side. In adjusting the die, the binding-screws E are first slackened, and the size required fixed by moving the taper-headed screws D D in or out; after which, the binding-screws E are set very tight the last thing. This die cuts screws with accuracy and finishes its work at one cut. The dies, while preserving the strength and reliability of the solid die, are not solid, but are adjustable for wear so as to keep the exact size of the taps, notwithstanding long use, and to allow of nuts and bolts for different purposes being made to fit together tightly or loosely as desired. When used up they can be replaced, the stock, colleta, etc., remaining good. The collets holding the dies have guides for starting bolts true; but when desirable to cut close under the heads of bolts, the face side of the die is used.

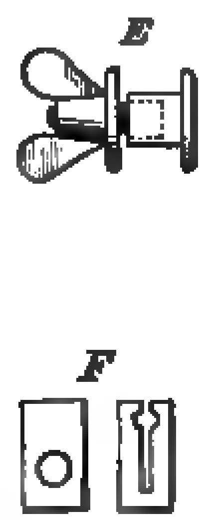
3828.



Pipe Stocks and Dies.—These tools differ from those hitherto described, in that the stock contains a guide to steady the pipe and conduct it true to the die. In Fig. 3828, A is the stock, containing the box B for the die I. The box is covered by the cap D, which is secured shut by the screw E. The guide F has its bore made to suit the external diameter of the pipe to be threaded, and is fixed by the set-screws shown at G. The end of the work is passed through the guide F. H is a handle detached. J. R. (in part).

SCRIBING-BLOCK. This tool, which is used for marking out work previous to sawing or cutting, is made in a variety of forms, but the simplest and best form is that shown in Fig. 3829, in which D is the block complete, the scriber being a simple piece of round steel wire. The dotted line on the foot is the distance to which the foot is hollowed out to make it stand firm. E is the bolt and nut; the bolt has a flat side filed on each side of it to fit it to the slot in the scribing-block stem, so that the bolt cannot turn when it is being tightened. F is a face and edge view of the piece or clamp for the scriber which passes through the hole in the slot. The advantages possessed by this form over other forms of scribing-block are, that it is easy to make, and that the scriber, being a piece of wire, is easily renewed. It holds the scriber very firmly indeed, and the scriber may be moved back and forth without the nut becoming slack; an object of great importance, not attainable in the common forms in which this tool is made. J. R.

3829.



D

SCRUBBER. See GAS, ILLUMINATING, APPARATUS FOR.

SEAMING MACHINE. See PRESSES.

SETTLER. See AMALGAMATING MACHINERY.

SEWERS. See DRAINAGE.

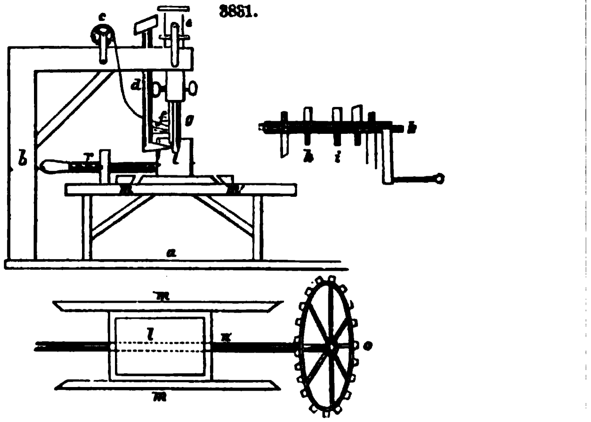
SEWING MACHINES. The essential parts common to all sewing machines are: 1. An eye-pointed needle, which by suitable mechanism is caused to carry the thread through the fabric; 2. A device for forming the stitch by looping or locking the thread; 3. A "take-up" to close the stitch upon the goods, and to prevent the thread from flying loose during the up stroke of the needle; 4. A "tension" device to regulate the strain applied to drawing the stitch tight in the fabric; 5. A feed-motion, by means of which the work may be fed through the machine at given speeds, so that the length of stitch may be varied at will; 6. A device for holding the fabric down upon the work-table and feed-plate while being sewed. These various portions are the result of combinations of many inventions and of a progressive development. The parts which overshadow all others in relative importance are the eye-pointed needle and the "four-motion" feed.

The Running Stitch.—The aim of the first inventors of sewing machines was to make a running stitch. Heilmann in 1829 took the centre-eyed, two-pointed needle devised by Weisenthal in 1755, and embodied it in an embroidering machine, where several such needles were similarly actuated over a moving web of cloth, so as to repeat patterns at various points from one governing design. John J. Greenough in 1842 used a needle similar to Weisenthal's, which he pulled through the cloth by nippers. Bean in 1843 corrugated the fabric and pushed it on an ordinary threaded sewing needle; and numerous other inventors pursued the same idea. It will be noted that the running stitch is here persistently aimed at, and the same object has been followed up to the present time, the latest form of machine for the purpose using a spiral needle and making an overhand stitch along the edges of bags, as described farther on.

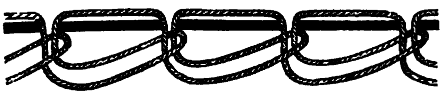
The Chain or Crochet Stitch.—While some inventors worked in this direction, others endeavored to produce the chain or tambour stitch. This is shown in Fig. 3830. It is formed by passing a thread through the fabric, forming a loop, then making a second loop and passing it through the first, and again making a third and passing it through the second, and so on. This is the stitch made by the hooked needle in crochet work. Thomas Saint in 1790 was the first to produce this

stitch by machinery, and his apparatus, probably the first sewing machine ever made, is represented in Fig. 3831. *a* is the bed-plate; *b*, an upright post bearing a horizontal overhanging arm, upon the end of which are placed a needle *f* and an awl *g*, adjusted by means of set-screws and moved by cams *h* and *i* on the shaft *k*. The awl first made a hole in the fabric; then the needle, engaging the thread in a notch on its lower end, descended through this orifice, and one loop was carried over the other by the bent point of the spindle *d*. The work was supported on a box *l*, sliding between guides *m* and moved by a screw *n* turned by a toothed wheel *o*, which in turn was moved upon the shaft *k*. The screw *r* adjusted the box *l* on the guide-plate. In 1804 Duncan in England arranged an embroidering machine with crochet needles, which after passing through the fabric received thread from a feeding needle and drew it back, pulling one loop through the other. Barthélemy Thimonnier in France, in 1830, devised a sewing machine in which the crochet needle was also used to make a chain stitch. His needle passed through the fabric, caught a lower thread from a thread-carrier and looper beneath, and brought up a loop, which it laid on the upper surface; then descending again, it caught another loop and enchained it with the previous one, and so on. Saint's machine made its chain with loops on the *under* side, while Thimonnier's produced its loops on the *upper* side of the cloth.

3831.



3830.



It will be noticed that all the needles thus far described are hooked or notched, or else have the eye in the end opposite the point, or in the middle. In 1841 Newton and Archbold in England devised the first needle with the eye at the point. It might be considered as developed either by carrying the point of the hook of the crochet needle to join the shaft, or by connecting the points of the notched needle. The above-named inventors used the eye-pointed needle to carry a thread through the fabric and leave a loop on the other side; then a hook caught the loop and drew it lengthwise over the spot where the needle would pass through on its next descent.

The eye-pointed needle making a chain stitch appears in many modern machines, and the date of its invention marks also the entering of inventors into another diverging path, which has led to the construction of the Willcox & Gibbs machine of the present day. This apparatus for some time made a simple chain stitch, which could easily be unraveled; but, as is fully described in referring to the machine farther on, an ingenious appliance puts a twist in the stitch which obviates this difficulty.

The Double-Loop Stitch.—In 1844 Fisher & Gibbons patented in England a curious mode of looping one stitch with the loop of another. A lower curved eye-pointed needle, carrying the thread, passed up through the fabric. An upper eye-pointed needle then entered between the lower one and its thread, and the curved needle descended and left a loop upon the upper needle, the fabric being fed the length of a stitch. The curved needle again ascended, and at the same time the upper needle was moved in such a manner that it passed the thread around the curved needle, and then retired through the loop of the needle thread previously on its stem. After this the upper needle, again advancing, entered between the curved needle and its thread as before, and the movements were repeated. The Grover & Baker machine (which see) embodies a modification of this peculiar construction.

The Lock Stitch.—The great advantages of the eye-pointed needle, however, were never fully proved until the invention of the lock stitch. This is always made by passing loops of thread through the fabric by means of an eye-pointed needle, and then passing another thread through these loops, the second thread as it were locking the first in place, as shown in Fig. 3832. When both threads are drawn equally tight, the position of each thread is the same relative to the sides of the cloth, the

3832.

3833.

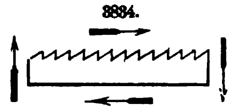
locking or overlaying taking place in the body of the fabric. This is shown very much exaggerated in Fig. 3833. It will be apparent that to make this stitch some means must be employed to carry the under thread continuously through the loops of the upper one. There is a sort of analogy between this operation and the carrying of the weft through the warp-threads of a loom, and this possibly suggested the use of a shuttle for the purpose. Between 1832 and 1834, Walter Hunt of New York conceived this idea, and built machines embodying the eye-pointed needle and a shuttle; but he neglected to protect his invention as required by law, so that in 1846 Elias Howe, who by independent study had reached similar results, was allowed to patent them, while Hunt, who subsequently attempted to assert his prior claims, was denied similar protection on the ground of abandonment. Howe made a curved eye-pointed needle, and caused his shuttle to reciprocate and so carry the lock-

ing thread through the loop, by means of two strikers on the ends of vibrating arms worked by cams. Since Howe's time modifications of the shuttle mechanism have multiplied with great rapidity. Many of these will be specially noted in referring to the classification and construction of modern machines. One point in this connection, however, will suggest itself to the mechanic, namely, that a locked loop can be made not merely by passing a thread contained in a moving shuttle through the loops, but also by carrying the loop over the thread wound upon a stationary bobbin. This latter idea was put in practical shape by Wilson in 1851; and the rotary hook which carries the loop about a fixed bobbin is the essential feature of the modern Wheeler & Wilson machine.

The Feed-Motion.—In all the early sewing machines the arrangements for feeding the cloth to the needle were crude and imperfect. In Greenough's machine the material to be sewed was held between clamps provided with a rack, which was moved to and fro alternately to produce a back stitch, or continuously forward to make the running stitch. The feed was continuous to the length of the rack-bar, and then the latter had to be set back. The intermittent automatic feed in Saint's machine has already been explained. In Howe's machine the cloth was attached to a baster-plate, and carried along before the horizontal needle to the end of the plate's motion. Then the machine was stopped, the parts were brought back to their first position, and the operation was begun again.

In 1852 Mr. A. B. Wilson devised the four-motion feed—an invention remarkable for its entire originality and its admirable adaptation to its purpose. It has never been successfully superseded. The manner of its operation will be understood from Fig. 3834. The device consists in moving a serrated bar, in a slot in the horizontal plate upon which the cloth is fed, in the direction of the four sides of a parallelogram. The teeth carry the cloth forward while moving horizontally a short space above the surface of the plate; the bar then drops (the second motion), then passes backward horizontally beneath the plate (the third motion), and rising brings the teeth through the slot and above the surface (the fourth motion). The directions of these movements are indicated by the arrows. The motion which carries the cloth forward is so timed as to take place while the needle is raised above the cloth, and never to interfere with its passage. By limiting the extent of this motion the length of the stitch is easily adjusted.

3834.



Among other feed-motions invented was a notched wheel which rotated with its upper edge just passing through a slot in a horizontal plate. An intermitting motion was given to this wheel, the movement alternating with that of the needle through the fabric. This arrangement was used with some success in the early machines of Singer and others. Mr. I. M. Singer also devised a feed-motion above the cloth, the presser-foot moving the material forward by means of its roughened under surface. The first continuous feed was probably that devised by Batchelder, who used an endless band or cylinder studded with a row of points which carried the fabric to and past the needle. Wilson's four-motion-feed patent expired after two extensions in 1871, and the Batchelder patent, which also was twice extended, terminated in 1877. In 1856 the Wheeler & Wilson and Grover & Baker Sewing Machine Companies, I. M. Singer & Co., and Elias Howe, Jr., united in a combination which controlled the eye-pointed needle and shuttle and the four-motion and continuous feeds, and which was thus enabled to dominate the entire sewing-machine trade. With the expiration of the Batchelder patent in 1877 the last important claim of the contracting parties ended, and, the competition of smaller manufacturing concerns being rendered possible, a large reduction in the price of sewing machines resulted.

Classification of Sewing Machines.—The most general classification of sewing machines is with reference to their specific uses. I. The term "sewing machine," without further qualification, is applied to apparatus for sewing ordinary fabrics. II. Waxed-thread sewing machines are of peculiar construction, and are used for sewing harness, sides of shoes, and leather generally. III. Shoe-sewing machines are a special variety used for fastening together the soles and uppers of shoes and boots. IV. Buttonhole- and eyelet-making machines stitch the edges of the apertures named. V. Book-sewing machines sew together the sheets, or sets of pages called "signatures," which make up the body of a book. VI. Bag-sewing machines may be recognized as a distinct class, when their work is to make an overhand stitch in the edges of bags.

I. Sewing Machines for Ordinary Fabrics.—These are classified according to the stitch which they make, and are consequently known as (1) lock-stitch, (2) single-thread chain-stitch, and (3) double-thread chain-stitch machines.

(1.) Lock-Stitch Sewing Machines.—There are two principal methods of making the lock stitch, namely: by the rotary hook or looper, which carries the loop of the upper thread around the stationary bobbin on which the under thread is wound; or by the moving shuttle, which transports the locking or under thread through the loop of the upper thread. These machines are respectively known as rotary-hook and shuttle machines.

Rotary-Hook Machines.—*The Wheeler & Wilson Sewing Machine*, manufactured by the Wheeler & Wilson Sewing-Machine Company of New York, is represented in Fig. 3835, and its details in Figs. 3836 to 3841. This machine is the best representative of its class, and is remarkable for the many ingenious and novel devices which distinguish it from all others. Fig. 3835 represents the so-called No. 8 machine, which has some special features noted in particular hereafter. Of other forms as made, the Nos. 6 and 7 machines are the principal. The following description covers the general features of all.

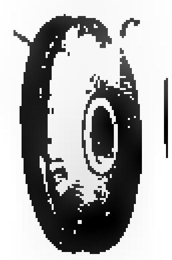
It has been explained that the rotary-hook machine makes its lock stitch by transporting the loop of thread over a fixed bobbin. The hook or looper for this purpose is of peculiar form, as shown at *A*, Fig. 3836, the tail or guard overlapping the point, so that the under thread from the bobbin *C* cannot interfere with the loop from the needle. The bobbin is inclosed in a case *D*, which covers one side and the mouth or opening between the sides. This case permits the loop of upper thread

THE WHEELER AND WILSON SEWING MACHINE.

to be carried around the lower thread without disturbing the position of the bobbin, and prevents the loop from being cast off the hook into the wide mouth of the bobbin instead of passing around

3837.

3836.



it. At *B* is the washer. In order to accommodate the motion of the hook to the action of the take-up—or in other words, to produce a variable motion between the driving-shaft and the hook-shaft, so that while the velocity of rotation of the former is uniform, that of the latter shall be

3838.

alternately accelerated and retarded—an ingenious variable-motion device is used, which is illustrated in Fig. 3837. It consists of a circular disk 81, revolving in a fixed yoke 80, and eccentric to the axes of the driving- and hook-shafts, which lie in the same line. On opposite sides of the centre of this disk, and lying along the same diameter, are two slots. A pin, 35, from the flange 82 of the driving-shaft 12, works in one of these slots, giving a variable motion to the disk by reason of the disk's being eccentric to the shaft. The other slot receives a pin 36 from the flange 15 of the hook-shaft 18, which thus receives a motion alternately accelerated and retarded to a greater degree than that of the variable-motion disk. The amount of variation of motion depends, of course, upon the amount of eccentricity of the disk, and the distances of the pins from the centres of the flanges.

3839.

Fig. 3838 is a view of the machine from beneath. At 4 is shown the means of actuating the needle-bar and take-up lever. At the lower end of the former is a stud and roller which enters the cam on the convex surface of the cylinder 4. The connecting rod 73 of the take-up lever receives motion from the cam 5 on the face of the same cylinder. This cam is fixed upon the driving-shaft, which is connected with the band-wheel 11.

The action of the machine will be understood from Fig. 3839. The needle, descending, carries a bight of thread through the goods and into the cavity of the hook, the take-up lever letting down thread enough for this purpose. As the needle begins to rise a loop is thrown out, which is immediately entered by the point of the hook, as shown at 1, the under thread from the bobbin being held clear of the loop by the tail of the hook, as shown at 2. The needle, having cleared the circumference of the hook, but still having its eye below the fabric, pauses, while the take-up lever descends and gives out thread enough to complete the loop, which is expanded by the hook and carried around the bobbin. This part of the revolution of the hook is performed on its

faster motion. The loop having been carried around the bobbin and cast off the hook, and the needle having risen entirely out of the goods, the take-up draws up the loop and completes the stitch. While the stitch is drawing up, during the interval between the casting off of one loop and the entering of the next, the hook is on its slower motion.

At the moment of drawing up the stitch, the apparatus for securing and regulating the under tension comes into play. This is represented, detached from the machine, in Fig. 3840, in which 1 is a hook-washer, of which the projecting pad 2, when in position, overlies the periphery of the hook; 4 is a plate which is screwed to the frame of the machine; 3 is a perforated finger held in proper direction on the plate by dowel-pins, which leave it free to be lifted from the plate; the needle, at every descent, passes through the hole in the tension-finger, and through it also passes the under thread; 5 is a horizontally movable lever, one extremity of which bears upon the tension-finger. At each revolution of the hook, the pad 2 is brought in contact with the tension-finger 3, clamping the lower thread when the take-up is completing the drawing up of the loop and tightening the stitch. The degree of under tension is varied by moving the lever 5, thus bringing it to bear upon one or

3840.

3841.

another point of the finger, and causing the latter to exert a greater or less pressure upon the pad. When the stitch is completed the pad moves away from the finger and releases the under thread from tension.

The feed generally used in this machine is a modification of the well-known four-motion feed of A. B. Wilson, the arrangement of which is represented in Fig. 3841. At each revolution of the hook the feed-bar 7, with its point 26, is raised, moved forward, and allowed to drop by the action of the feed-cam 39, which is attached to the hook-shaft; the bar is then thrown back by the spring 38. This machine is also provided with the "wheel-feed," when desired for certain special kinds of leather stitching. The length of stitch is regulated by the eccentric stop 27, which is attached to the cloth-plate of the machine, and may be turned as desired by means of the small lever.

The machine represented in Fig. 3835 is more especially adapted for family use and light manufacture; and for such uses it has some special features. The needle-bar is actuated by an eccentric and connection, instead of by a cam; the variable motion of the hook is obtained by placing the driving- and the hook-shaft in different lines, and connecting them with cranks and a link; the length of stitch is regulated by the movement of a knob on the upper surface of the bed-plate; the take-up is simplified, and the under tension is regulated by means of a thumb-screw. To facilitate the placing and removing of the bobbin, the ring-slide or bobbin-holder is hinged.

The following tests made by the judges at the Centennial Exhibition of 1876 will serve to show the capabilities of the machine: "One of the tests was, to stitch book-muslin with No. 400 cotton at the rate of 600 stitches per minute. To test the ease with which it runs, two thicknesses of muslin were stitched together with No. 60 cotton at a speed of 600 stitches per minute, with the same cotton used as a driving-belt. On patent enameled leather, and without injury to the surface, lines of stitching were made, containing over 100 perfect stitches to the inch. Bags of both India-rubber and kid were stitched perfectly water-tight at the seams. As tests of the heavy material which may be sewed by it: In one case 18 thicknesses of 'butternut' duck were sewed together; and in another 6 layers of tin, alternating with 7 thicknesses of heavy broadcloth, were all stitched together without any previous puncturing of the tin. To test the variation in thickness of the work which is permissible without change in the adjustment of either tension, seams were made passing successively from one to three and four thicknesses of leather, thence to muslin and to the thinnest tissue paper. Calf-skin and India-rubber were sewed together, and the feats of making seams with copper wire instead of thread, and using a purposely knotted under thread, were successfully performed; and the machine was finally run at a speed of over 2,000 stitches per minute. In a reciprocating-shuttle machine, this would necessitate 4,000 single excursions of the shuttle per minute, or $66\frac{2}{3}$ in a second of time."

SHUTTLE MACHINES.—These machines outnumber all other forms, and with regard to construction are of two principal varieties: 1st, those having oscillating shuttles, which move in a curved path in a vertical plane; and 2d, those having reciprocating shuttles, which move in a curved or straight path in a horizontal plane, either (*a*) at a right angle to the needle-arm, or (*b*) parallel to the same.

Besides the machines above named, others have been constructed having rotary shuttles and stationary shuttles; but these have not come into any extended use, and hence are not specially described.

Oscillating-Shuttle Machines.—The Wilson Sewing Machine, manufactured by the Wilson Sewing-Machine Company of Chicago, is represented in perspective in Fig. 3842. The working parts beneath the machine are clearly shown in Fig. 3843. The shuttle is separately represented in Fig. 3844. In the shuttle is placed the bobbin 97, the thread from which is carried through a slot 98, under and between tension-disks 99, and around a tension-stud 100, and thence through the hole and guard-spring 96 and 95. A swing-cap is then brought over the bobbin, and the shuttle is placed on a carrier in a circular race, a front view of which is given in Fig. 3842. In Fig. 3843, 69 is the oscillating

THE WILSON SEWING MACHINE.

shaft that operates the shuttles, and 70 is the rotary shaft which actuates the feed; 78 is the stitch-regulating cam; 73 is the feed-cam; 75 is the shuttle-race; 77 is the feed-bar pin; 19 is the stitch-regulating nut; 79 is the feed-regulating screw; and 72 is the feed-regulating clutch. Also at 73 is shown the spiral feed-spring.

3843.

The shafts 69 and 70 are actuated respectively by the eccentric pitman 58 and the pitman-oscillating crank 57. Both of these receive motion from the eccentric on the main shaft, shown in Fig. 3842. At 36, in Fig. 3843, are take-up screws, at 60 is the rotating shaft-crank, and at 62 the shaft-crank pins. It will be evident that as the shuttle-carrier oscillates, the shuttle is carried to and fro through the loop, the point of the shuttle entering the latter as the needle descends into position. This machine is notably simple in construction and easy in operation. It is provided with an ingenious take-up attached to the side of the needle-bar case, which draws up the shuttle

3846.

3845.

thread, tightens the stitch, takes thread from the spool, and keeps the slack thread away from the needle point until the needle enters the fabric.

Machines having Reciprocating Shuttles.—(*a*) *Shuttle moving parallel to needle-arm.*—*The Singer Sewing Machine*, manufactured by the Singer Sewing-Machine Company of New York, differs from other shuttle machines in the direction of the movement of its shuttle as above indicated. The shuttle itself is shown in Fig. 3845, and will serve as an example of the usual form of the appliance in most machines into which it enters. *A* is the body, *B* the bobbin wound with thread, and *C* the thread-guide. Fig. 3846 represents the shuttle *A* placed in the shuttle-carrier *E*, with the point of the shuttle just entering the loop.

(*b.*) *Shuttle moving at right angles to needle-arm.*—*The Household Sewing Machine*, manufactured by the Keats Machine Company of Providence, R. I., is represented in Fig. 3847. The shuttle-lever receives motion from the eccentric lever connected with the main shaft, through a universal joint, the eccentric lever being held in a swivel. This swivel is supported on pointed centre-screws, one of which is adjustable by means of a check nut. At the upper end of the eccentric lever is a hardened

wedge, which by means of a screw may be adjusted so as to take up any wear. Hardened steel washers, concave on one side, fit against the ball which forms the universal joint so as to give it a large bearing surface, and the ball itself is split and provided with a taper screw so that it may be expanded. The feed-bar is not pivoted at one end as is usual, but has a spring-seat, so that it may be raised parallel to the bottom of the presser-foot. The shuttle has an open end, with the bobbin resting upon the shuttle-carrier. The use of a head-piece is thus obviated, and by this means it is claimed that a greater quantity of thread can be used. Other distinctive features of this machine are as follows: The band-wheel can be tightened or loosened on the shaft at will, to facilitate winding of the bobbin. The tension-bracket, having a rocking seat, presents a parallel surface to the tension-spring in all positions. The lifter has a triple cam, so that it may be adjusted to raise the presser-foot for ordinary work, and the foot-hemmer into position for receiving cloth for hemming, or to remove both foot and hemmer The needles are made with shanks of different sizes, corresponding to sizes of blade, so that each blade is brought the same distance from the shuttle. The needles are also self-setting. A needle-guard of steel between the shuttle and needle prevents breakage of the latter.

The New Home Sewing Machine, made by Johnson, Clarke & Co. of New York, is represented in Fig. 3848. The shuttle-carrier is a bell-crank pivoted beneath the machine, and receiving motion from a horizontal eccentric by means of a link. The feed-lever is actuated by a cam on the vertical shaft, and its motion is governed by a stitch-regulator bar which moves in longitudinal ways beneath the plate. The chief feature of this machine is the fewness of its working parts. Other peculiarities of construction are clearly shown in the engraving. The special advantages claimed for it are a self-setting needle, an automatic tension, a means of winding the bobbin without running the entire machine, a dial for regulating the length of stitch, a spring tension-shuttle, a self-acting take-up, a powerful feed-motion, and easy adjustability of all parts.

3849.

The White Sewing Machine, manufactured by the White Sewing-Machine Company of Cleveland, Ohio, is represented in Fig. 3849 The shuttle is here caused to reciprocate by a pivoted lever, which receives motion from a lever-arm and ball. To this arm a to and fro motion is imparted by suitable connection with the eccentric on the main shaft. The feed-lever also derives motion from this eccentric, and imparts it to a disk on the end of the feed-arbor under the machine, as shown. At the opposite extremity of the feed-arbor is the feed-cam. On the side of the machine opposite the cam

is the feed-screw, by adjusting which the stitch is lengthened or shortened. The feed is double—that is, on both sides of the needle—so that the operator can carry the fabric through either side as desired. This feature, and the large space under the arm, are special advantages claimed for this machine. The shuttle is self-threading, is of solid steel, and carries an extra-large bobbin. The shuttle-tension is so arranged that it can be increased or diminished without removing the shuttle. Set-screws are provided in all boxes and bearings, so that any lost motion due to wear can be at once taken up.

The Domestic Sewing Machine, made by the Domestic Sewing-Machine Company of New York, is represented in Fig. 3850. Near the right-hand end of the main shaft and within the arm are two eccentrics from which motion is given to the feed- and shuttle-levers beneath the machine. The shuttle is provided with a spring-latch pivoted to it, which extends along the shuttle, and is bent to close the open end of the latter. The spring rests on the thread and gives it the necessary tension. The shuttle is placed loosely in the fingers of the swinging carrier or lever, and inclines downward and outward to the left against the upright inner face of the race in the bed of the machine. The take-up for the government of the thread is a combination of the spring and the positive methods. The strain that it puts on the thread is modified by the spring, but the action which relieves the strain is positive. The fly-wheel may be made tight or loose on the shaft, as desired. The shuttle-lever is forked at one end to receive the ball-like extremity of the vertical lever pivoted to the standard and embracing a cam or eccentric on the main shaft. The latter actuates the needle-bar by means of a crank-pin at its outer end, which enters a curved slot attached to the bar. The four-motion feed derives its

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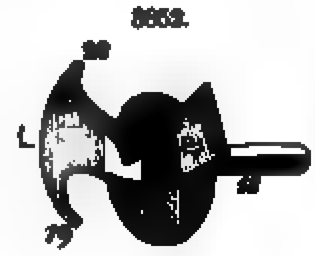
3852.



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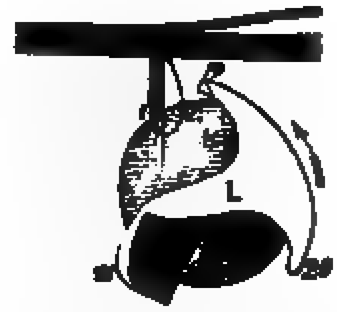


motion from a bell-crank actuated by a horizontal lever, moved by a vertically reciprocating connecting-rod which is driven by an eccentric on the main shaft.

(2.) Single-Thread Chain-Stitch Machines.—*The Willcox & Gibbs Sewing Machine* is the chief representative of this class. The shaft of the machine is operated, as is usual, by a belt from a large wheel driven by a foot-treadle. An eccentric on the main shaft moves a pitman which causes the vibration of the pivoted arm or lever, to which is connected the needle-bar, which is thus reciprocated up and down. The needle, which is straight, passes up within the needle-bar, and is clamped in place by a nut which is screwed upon the lower split end of the latter. The presser-foot is supported by the stationary G-shaped arm of the machine, and serves to hold the fabric in place upon

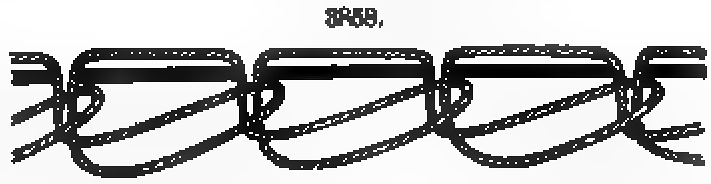
the table. The presser-foot is held down by a spring, and is lifted by a small cam-lever. The general construction is shown in Fig. 3851, upon which the names of the parts are marked.

The essential features of the Willcox & Gibbs machine lie in the mechanism for producing a twisted-loop stitch, which was patented by Mr. J. E. A. Gibbs, and in the automatic tension devised by Mr. Charles H. Willcox. In the stitch mechanism, a rotating hook causes the relations of the threads on each side to become changed toward each other. The different parts of the hook are shown in Fig. 3852, in which 18 is the shank, 19 the point of the hook, 20 the "cast-off," and 21 the heel. *K K* is the shield for protecting the thread from oil. In Fig. 3853 the needle, having descend-

3854. 3855. 3856. 3857.

ed to the lowest point, carrying down the thread, has just begun to ascend; and a loop is thrown off on the back side of the needle just in time for the point of the hook to enter it. As the needle rises, the hook, moving in the direction of the arrow, passes into the loop, drawing it down and spreading it. As the hook advances from this point the loop begins to twist; thread No. 1, Fig. 3854, moving to the right, slides off the shoulder at the centre of the hook and falls down to the shank, near the shield *K*, while the heel, 21, catches the back side of the loop 2, and swinging it around passes into the loop which is being reversed. As the hook still advances and the heel passes farther into the loop, thread No. 2 slides into the angle at the centre of the book, as seen in Fig 3855. The loop is now completely reversed, thread No. 2 being on this side of the needle, and thread No. 1 on the back side. While the old loop thus twisted and spread out is held open on the body of the book, the point 19 enters the new loop and carries it into the old one, as seen in Fig. 3856; and as the hook continues to revolve, the cast-off, 20, passes out of the old loop and leaves it to be drawn up to the under side of the fabric, as in Fig. 3857, which completes the stitch.

3858.



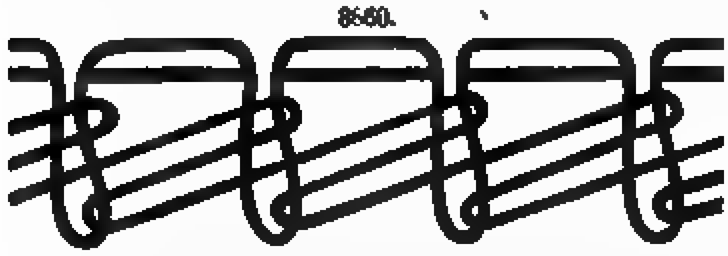
The position of the thread in the twisted-loop stitch is shown in Fig. 3858. In Willcox's automatic tension, instead of subjecting the thread (the spool containing which is placed on a carrying peg above the fixed arm of the machine) to a continuous tension produced by partially confining it in a groove or clamp through which the motion of the machine draws it, it is made to pass between two disks, held together by a spiral spring firmly enough to hold the thread inflexibly and to draw it through the fabric to a definite distance, until more is required to make a new loop. The strain is then relieved by a small rod striking against the lower end of another rod attached to the upper disk. A uniformity in the drawing up of each stitch is thus secured, and as the necessity for change in tension when different sizes of thread or thicknesses of cloth are used is done away with, no provision is made for change by the operator.

As shown in Fig. 3851, the main shaft extends under the machine, and an eccentric on this, back

of the rotating hook, enters a slot in the feeding bar and gives it the usual four motions. The length of the stitch is regulated by an eccentric lever, by means of which the play of the feed-plate is restricted at will.

(3.) DOUBLE-THREAD CHAIN-STITCH MACHINES.—*The Grover & Baker Sewing Machine*, shown in Fig. 3859, uses two needles, an eye-pointed needle above and a curved eye-pointed needle or looper beneath the cloth-plate. Motion is given to the lower needle *G* as follows: In the end of the lower vibrating arm is a slot, in which stands the post *T* resting on a fixed step. The portion of this post which passes through the slot in the arm is flattened and of a spiral form, so that it is caused to make a half revolution by the upward and downward motion of the arm. The under thread is taken directly from the original spool *K*, thence passes through the guide *L*, and thence to the looper. The relative motions of the upper needle (which is curved) and the looper are so timed that they alternately enter the one into the other's loop, and thus produce the stitch shown in Fig. 3860. The tightening of this stitch makes a firm knot. The upper needle is attached to the end of the vibrating arm *C*. The main shaft *R* rotates under the bed-plate *A*, and is placed at right angles to the direction of the arm *C*. A double cam on this shaft, combined with a spring, gives motion to the ordinary four-motion feed. The length of stitch is varied by the time which the feeder is kept out of contact with the cam at the end of the backward stroke. *B* is the stationary arm to which the presser-foot *D* is attached. The upper thread, the spool of which is shown at *H*, gets its tension by passage through metal disks *I*, and thence passes directly through plain guides to the needle. A light spiral spring at *O*, over which the thread passes, serves to kee
when the strain is relieved by
pair of small nipper-springs, w
hold it back long enough for

3860.



3861.

II. WAXED-THREAD SEWIN
chiefly used for sewing up
shoes, in harness-making, and
ing stitching of leather. Ex
the lock-stitch and the chain-

The Keats No. 1 Wax-Thre
ufactured by the Providence
dence, R. I., is a lock-stitch m
alike on both sides, with threa
hard wax. Referring to Fig
follows: Power is transmitte
by means of a horizontal sha
tion-pulley 30, and also the d
is caused to come in contact
right shaft, by pressure on t
11 incloses the stitch-register
upper end, and records the re
13 is a hand balance-wheel.
ing motion, through lever 3
Attached to cam 38 is cam
presser-bar lever 40 and pre
pose of relieving to a certain extent the pressure on the material while the feed is acting. Cam 36 operates lever 41, for the purpose of giving motion to the shuttle. Cam 35 operates the separator 46, the use of which is explained farther on. Cam 33, through the lever 34, gives horizontal motion to the feed. Cam 32, through a lever not shown, gives motion to the whirl-shaft 49; and cam 31 gives perpendicular motion to the feed through lever 25. By means of lever 28, cam 57 operates at intervals the brake 28, giving increased tension on the spool 24. At 45 is the shuttle-holder, and at 15 the crank-lever which operates it. At 56 is shown an extra face-plate for heavy work. The shuttle, which holds about 100 ft. of linen thread, is round, about 1¼ in. in diameter, and has a recess on the side of which is a hook to catch the thread-loop. The needle is straight and barbed. The operation of the machine is as follows:

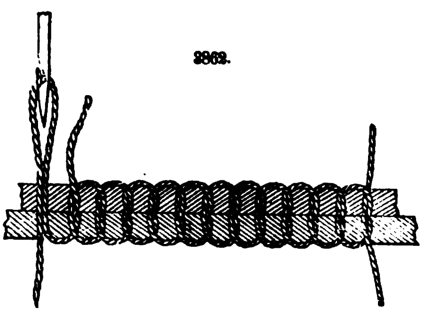
The spool 24, after being filled with hard-waxed thread by a waxing machine provided for the

purpose, is adjusted in place, and the thread is drawn up through the whirl- or looper-shaft 49, and thence through the needle-plate. The looper-shaft has an oscillating motion, and its object is to wind the thread around and upon the hook of the needle when the latter has fully descended. When the loop is drawn up on the hook of the needle to its extreme height, the point of the separator 46 enters the loop and spreads it. The needle next descends a short distance, simply to release the loop and leave it on the separator, and then returns. The instant the needle casts off the loop upon the separator, the hooked point of the shuttle enters it and starts around. On the upper side of the shuttle are two holes, opposite one another, above and corresponding to which holes are pins connected to an upright spindle inside the shuttle-box. These pins have a walking-beam motion, rising alternately, so that one of them is in constant contact with the shuttle, while they oppose no obstacle to the passage of the thread around the same. As soon as half the loop or one strand of thread is engaged in the hook recess in the shuttle, the latter oscillates, the pins lifting at the proper time to let the goods pass, and the feed-point moving the goods along. While the above is taking place, the needle descends, catches the under thread, and rises. Meantime, the hook on the shuttle has carried one side of the loop entirely around it. The two parts of the loop are thus brought together, and, the thread having just slipped off the separator, the loop is left with the shuttle-thread loose within it. The stitch is finally drawn tight and into the body of the material by the rising of the needle. Fig. 3862 shows the stitch and the manner of making it.

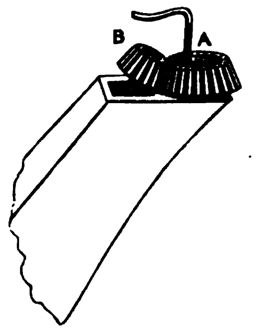
Loop-Stitch Waxed-Thread Sewing Machines.—In waxed-thread sewing machines which make the loop stitch, an awl is usually employed, which is driven downward through the leather by the upper mechanism. When the awl rises, the needle, which is hooked or barbed, follows it through the material, and receives a thread-loop from a small horizontally swinging arm, which is supported by the arm or upper portion of the machine. When the needle descends, it carries a loop of thread through the loop last formed. The feeding of the work through the machine is effected by a lateral movement of the needle.

III. Shoe-Sewing Machines.—The sewing machine for boots and shoes was for some time made similar to the ordinary leather-sewing machines. This, however, did not reach the inside of the

3862.



3863.



3864.

shoe in a satisfactory manner to sew the upper to the insole, although stitches could be put on the outside which sewed the soles together. The shoe-sewing machines as at present made produce either the loop or lock stitch.

The McKay Shoe-Sewing Machine is a lock-stitch machine, and has for its essential feature a device at the end of the jack, inside the shoe, which acts in concert with the needle. This device is called the whirl, and is represented at *A* in Fig. 3863. It is simply a small ring having bevel-teeth on its exterior, so that it is rotated by the pinion *B*. This pinion receives its motion by the rods and bevel-gearing, which communicates with a cam movement in the rear of the upper part of the machine. The whirl is placed at the end of a horn, and the waxed thread from the spool is led through a side aperture in it. The needle, represented in Fig. 3864, passes down through a central orifice in the whirl. A shoe is placed on the horn, and the stitching is commenced preferably at or near the shank. As the stitching proceeds, the horn is rotated, and the shoe moved thereon so as to bring it properly under the action of the needle. The end of the horn is covered by a plate in which is an orifice over the whirl. The hooked needle, after penetrating the sole resting on the horn, has the waxed thread laid in its hook by the whirl, and in ascending it draws a loop of thread through the sole and upper. A cast-off, *H*, Fig. 3864, closes the hook and prevents the escape of the loop while the shoe is moved for a new stitch; and when the needle next descends, it passes through the loop on its shank and draws a new loop up through it, in this way enchaining one loop with another. Just enough thread is drawn from the spool to form a stitch, this action being automatic according to the thickness of the material being sewn. The feed-point has a reciprocating motion which pushes the work under the needle.

The Goodyear and McKay Sewing Machine is of different construction from that described, it having a straight awl and circular needle. The latter works in a circle of less than 2 in. in diameter. Another important feature is the needle-guard, working concentrically with the needle, forming a brace which supports the point of the needle in entering the work and in drawing up the stitch, thereby preventing the springing or breaking of needles. In operation, this brace or support goes down with the needle until the point of the needle enters the work, and there remains until the needle returns, supporting it close to the barb, when the greatest strain comes upon it in drawing up the

stitch. The essential portions of this machine, the curved needle being represented as entering the shoe-sole, are shown in Fig. 3865.

The Keats Lock-Stitch Shoe-Sewing Machine, represented in Fig. 3866, is the same in shuttle mechanism and in general construction as the waxed-thread machine by the same makers, described on page 744. Its essential advantage is the production of the lock stitch. The shoe or boot, after

3866.

coarser thread either at top or bottom, as desired.

IV. Buttonhole and Eyelet-making Machines.—*The National Buttonhole Machine* is represented in Fig. 3867. The feeding mechanism is the peculiar feature of this machine, the stitch-forming mechanism being identical with the Wheeler & Wilson No. 7 machine. On the driving-shaft of the machine is fastened a switch-cam, which projects through an aperture made in the bed-plate. Working in this cam is a follower, which is adjusted at one end of one of two driving-levers. These have their fulcrums at their opposite ends, and are joined together by an adjustable link, which is secured to the driving-levers by means of sliding blocks. One of these levers is secured to a driving-plate gibbed on the bed-plate. To the opposite side of this sliding plate is attached a cloth-clamp and plate, between which is placed the material in which buttonholes are to be made. The reciprocating motion which the follower receives from the switch-cam is conveyed through the levers and sliding plate to this cloth-clamp, and gives the necessary vibratory motion requisite to form the buttonhole or over-edge stitch. This vibration is timed to take place immediately after the needle leaves and before it reënters the fabric. On this vibrating sliding plate is fulcrumed a feed-lever, which is also adjustably connected to a feed-arm gibbed in ways to the bed-plate. The vibration of the sliding plate imparts the motion by means of this arm and lever to a feed-dog, which revolves a ratchet-wheel. The revolution of this wheel gives motion through a variable-motion device to a wheel which is geared to a feed-disk, said wheel being revolved twice to one revolution of the feed-disk. This feed-disk is slotted in its upper surface. In this slot is adjustably connected a pitman which at the other end is secured to a feed-plate working two ways in an independent change-plate, which is adjusted upon the vibrator as shown. To this feed-plate is attached the cloth-clamp before referred to. The action of the feed-disk and pitman as a crank-wheel and crank imparts the feeding or longitudinal step-by-step motion to the cloth-clamp, moving the fabric placed therein in that direction, while the lateral reciprocating motion is imparted by means of the switch cam levers and vibrating plate before described, thus making the over-edge stitches along the side of the buttonhole. When the end of the buttonhole is reached, a cam correctly adjusted on the shaft of the feed-disk, working against a cam-strap, moves the independent change-

plate and the cloth-clamp attached thereto, bringing the unstitched side of the buttonhole under the needle, while the natural reverse movement of the pitman in the feed-disk or crank-wheel causes the material to be moved in the opposite direction, thus laying the stitches in this second side of the buttonhole the same as and parallel with the side first worked. The action of this cam-strap and change-plate is so gradual from side to side that a number of stitches are interlocked across the ends. Thus the buttonhole is automatically worked on both sides and barred at both ends without handling or stopping the machine. The quality or closeness of the stitches can be changed by moving the screw shown, which works in the feed-arm, thereby giving more or less motion to the feed-lever and ratchet, and consequently through the intervening mechanism to the cloth-plate and clamp, and its step-by-step movement mentioned above. The depth of vibration is changeable at will by the adjustable link connecting the two levers, which connect the follower in the switch-cam with the sliding plate. The length of buttonhole is varied as desired by the connection of the pitman with the slotted feed-disk. Moving this connection to the outer surface gives a longer buttonhole, and toward the centre a shorter one. The cutting space in the centre of this buttonhole is changeable by a thumb-screw that changes the fulcrum of the cam-strap against which the change-cam on the feed-disk shaft operates.

The National Eyelet Machine is the same as the National buttonhole machine so far as the stitch-forming mechanism and the cam on the driving-shaft, follower, and the two driving-levers are concerned. Connecting with the last of these two driving levers by an adjustable link is a third lever, fulcrumed to the bed-plate and connected at the other end with a sliding plate. The plate has fastened to it a dog operating on a ratchet-wheel which is located directly under the needle of the machine. This ratchet-wheel, the upper portion of which forms a revolving cloth-plate, has in its upper surface inserted a number of sharp points or pins. In the centre of this plate, and projecting through it, is a slotted finger or stud that is secured to a sliding cloth-plate. This sliding plate also has a slot cut in its surface to admit of the needle entering. This sliding cloth-plate is attached to the regular sliding plate of the machine, which gives it a vibratory motion, at the same time that the revolution of the ratchet-wheel and feed-plate gives the circular feeding action to the material. In the place of the cloth-clamp of the sewing machine is a circular foot that clamps the material securely to the revolving feed-plate, and, by its force in pressing the material against the slotted finger, causes this finger to perforate the material, making the hole of the eyelet. This hole is varied by using a larger or smaller finger. All variations of depth of vibration, qualities of stitch, etc., are accomplished by the moving of thumb-screws that change the fulcrums of the various levers.

V. Book-Sewing Machines are used to stitch together the sheets or signatures which make up the body of a book. In hand-binding, after a book has been pressed in the smashing machine, it passes to a sawing machine preparatory to sewing. Several volumes are taken together, and by means of revolving saws cuts (usually five) are made in the backs, of a size sufficient to admit the bands of twine to which the sheets are sewed. The sewer has a wooden frame, which consists of a table with two upright screws, supporting a horizontal and adjustable rod, to which three strong bands fastened on the table are attached at distances corresponding to the three inner saw-marks. The sewer places the first sheet against the bands, and passes the needle from the first cut or kettle-stitch to the inside of the sheet, then out and in at every band, embracing each with the thread, until the bottom is reached. The next sheet is sewed in the same manner, but in an opposite direction, and so on alternately until the last.

Smyth's Book-Sewing Machine, the invention of Mr. D. M. Smyth of Hartford, Conn., is represented in Figs. 3868 to 3873. This apparatus is remarkable not only for the great ingenuity of its construction, but for the rapidity with which it operates and the strength of its finished work. It is capable of sewing 60 signatures per minute, and inserts 8 separate threads if need be, any one of which may be cut or broken without impairing the holding of the others. The machine, which is represented in perspective in Fig. 3868, uses 8 spools, and is capable of sewing any book in length within the compass of its supporting-bar and up to 8 inches in thickness. On the left of the machine in Fig. 3868 is a pivoted upright rod *A* having four radial arms. This rod has an up and

down movement in its bearings, and also a movement of rotation. The attendant begins by placing a signature or folded sheet over the arm, which projects directly toward him. The paper is adjusted and held in place by means of a clip *B*. By the action of the cam shown beneath the machine and the arm connected therewith, the upright rod *A* is rotated and at the same time raised. Meanwhile the four presser-feet shown are swung upward, so that the sheet by the rotation and subsequent rising of the rod and arm is brought directly under the needles, when the pressers close down on it; at the same time a stop strikes the clip *B* and raises it. The signature is then in the position shown in Fig.

3868. Referring now to Fig. 3869, the clip B is shown raised. Working in guards on a cross-bar of the machine are two curved needles. One needle is shown in full size in Fig. 3870. A needle C, as indicated by the dotted lines, is represented in Fig. 3869 as having passed down through the back of the sheet. This it is enabled to do by a suitable recess made in the swinging arm. The point of the needle has an eye, and through this the thread has previously been placed. As the needle-point emerges from the paper a long horizontal needle comes forward from the rear of the machine and passes through the loop of the thread. The end of this needle just entering the loop is shown in Fig. 3869. The curved needle then is retracted, the supporting arm descends, and the sheet is left held up by the stitch and pressed back against the preceding sheets by the pressers. In the same way as already described, another signature is now brought into place. This time, however, the curved needle C does not act, but the stitch is made in precisely similar way by the opposite curved needle D, Fig. 3369. The loop from this needle is taken by the same straight needle as before, as its point comes out at the same place. It will be seen therefore that the needles C and D constitute, so to speak, a pair, and that they operate in turn on alternate signatures. From Fig. 3868 it will also be noticed that there are four pairs or sets of these curved needles, and that, as all work alike, the left-hand needles put the stitch in the first signature, for example, the right-hand ones in the next, and so on. This will be more clearly understood from Fig. 3871, which represents the backs of a series of sheets. Here the long horizontal needles which move out from the rear are shown at E, carrying the loops, the positions of the stitches in alternate signatures being indicated by the dotted lines. The object of thus alternating stitches is to make the finished book of even thickness. In Fig. 3872 are shown the horizontal needle and the sheets suspended therefrom by the loops, in perspective. In the end of the needle is an eye. After the desired number of signatures have been sewed, a piece of stout cord is rove through the needle-eyes, and then the frame carrying all four needles is retracted. The effect of this is to draw the cords through all the loops, thus firmly locking the stitches. It will be clear that not only are the pairs of adjacent stitches made by each pair of curved needles entirely independent of all other stitches made by other sets of needles, but that the stitch made by the right-hand needle of each pair is independent of the stitch made by the left-hand needle.

3871.

The mechanism by which the operations above described are effected is exceedingly

3870.

simple. An automatic tension keeps a uniform strain on the threads, and a novel clutch on the driving-wheel enables the operator to govern the action of the machine.

It may be added that this machine is but a single representative of a series of devices of similar nature by the same inventor. The principle of one of these, for sewing in strips of raw hide in the backs of heavy books, is represented in Fig. 3873. After the

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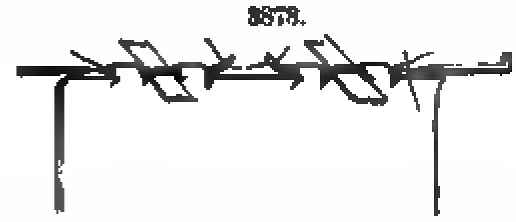

backs are sawed, each signature is so lifted and adjusted that certain portions of its edge are pushed aside. Eye-pointed needles then pass through the portions of the edge not bent down, and over the raw-hide strips laid in place, as shown. The stitches are locked in the middle as already described.

VI. Overhand or Running-Stitch Sewing Machines.—The principal representative of this class of apparatus is the Laing overhead sewing machine, used for stitching seams of heavy bags. An illustrated description of the mechanism appears in the *Scientific American*, xxxvii., 116. The peculiar feature of the machine is the means of making the stitch. The needle is caused to pass completely through the fabric from "overhead" to the under side, and then, passing upward round the edge, once more pierces and passes through the material, and so on. This is a copy of the action of hand sewing in making a seam where the thread or cotton continually encircles the two edges which are brought together to be united. This effect, or stitch, is produced by a circular helical needle, which makes two or three turns round a central spindle. The interior diameter of the circular needle is considerably greater than that of the spindle within it; and as the driving-

band is arranged by guide-pulleys to pass only round one side of the needle and spindle, the needle is thus pressed away from the spindle upon one side, and is suitably placed for piercing the material as it revolves. One end of the spiral needle is of course sharpened, and the other end by a hook engages the thread, and thus carries it through and through the material, making a lapping stitch round the edges of the seam, which cannot thus be distinguished from hand-sewing except by its regularity and evenness.

SEWING-MACHINE ATTACHMENTS. Auxiliary devices used in connection with the sewing machine to increase its capabilities. They are used with all forms of the sewing machine for ordinary fabrics, and for such do not materially differ in essential particulars. Those here illustrated are specially contrived for application to the Wheeler & Wilson machine.

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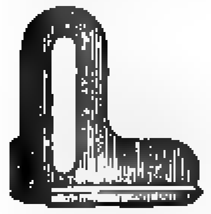

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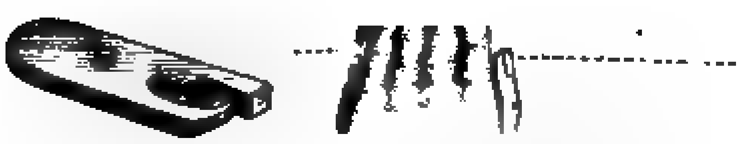

The Plate-Gauge, Fig. 3874, is attached to the cloth-plate by means of a thumb-screw, so that it can be set at any desired distance from the needle. It is used as a guide to enable a line of stitching to be made at uniform distance from the edge of the fabric.

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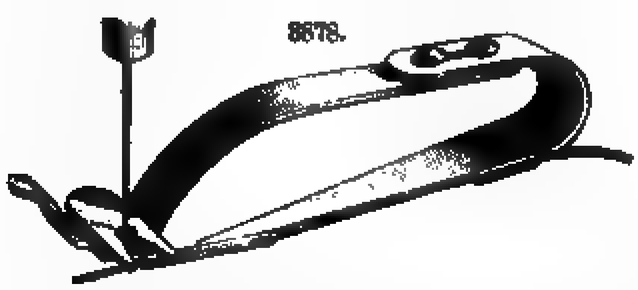

The Quilting or Bosom Gauge, Fig. 3875, is attached to the presser foot. The work is passed beneath it. The finger of the gauge is set to serve as a guide for the edge of a fold when stitching shirt-bosoms, or for a preceding line of stitching when it is used for quilting.

The Hemmer, shown separate in Fig. 3876 and attached in Fig. 3877, is substituted for the ordinary presser-foot. The fabric to be hemmed is passed with its edge entering the scroll, the latter being so shaped as to fold the edge of the cloth over twice, as is done in hand-hemming. The fold then passes under the needle and is stitched down.

3881.

3880.

The Corder, shown separate in Fig. 3878 and attached in Fig. 3879, is used to place a cord between thicknesses of cloth. It is attached to the presser-foot, and has a tube which conducts the cord close to the line of stitching which holds it in place.

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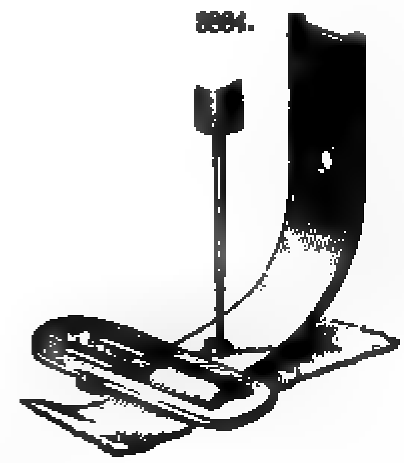

Rufflers are used for making ruffles on fabric while the same is being stitched, the ruffle being gathered and the band sewed simultaneously. This is done in two different ways. Fig. 3880 shows a ruffler in operation. In this method the band to which the ruffler is to be sewed is passed through the upper guide and above the separating plate, while the ruffle is led through the lower guide and below the separator, the latter being so set that the feed will first seize the ruffle and carry it forward until the teeth pass the edge of the separator and engage the band

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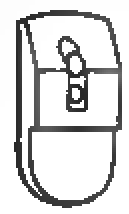

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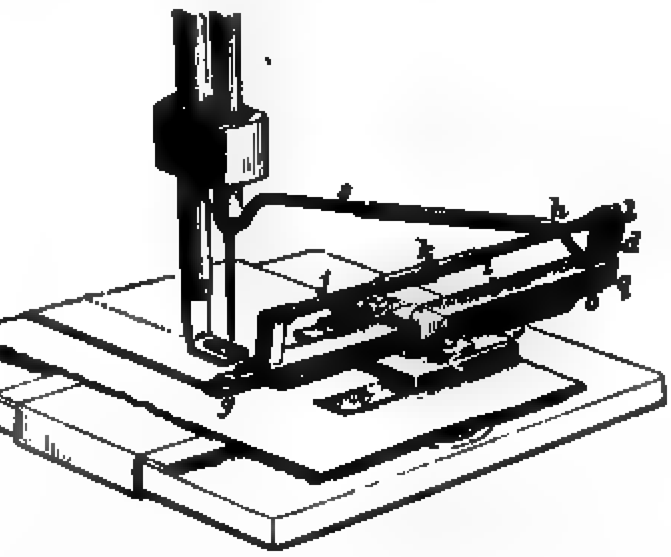


also. Both are then moved forward together, the ruffle being moved a greater distance than the band at each stitch, thus causing its fullness, the amount of which is controlled by the small lever shown above the device.

In Toof's Standard ruffler, represented in Fig. 3881, the ruffling mechanism is entirely independent of the feed. The advantage of this is that the ruffle, being placed above the band, can be plainly seen and more easily regulated to the desired fullness. The gathering mechanism consists of a blade or knife, which either pulls the ruffle into gathers or folds it into a succession of small plaits. The device is attached to the bed of the machine by means of the thumb-screw 7. The ruffling blade is actuated by the lever 2, which connects it to the needle-bar, and the fullness is regulated by the star-shaped screw near the lever.

The Binder, and the same in place, are shown respectively in Figs. 3882 and 3883. It is attached to the cloth-plate by screws. The material is passed through it as shown, and guides are set to the proper width. Fig. 3884 represents the seam-stay foot or trimmer, which is used for stitching stay-binding over seams to strengthen them, and also for sewing trimming upon clothing. It is substi-

tuted in place of the ordinary steel presser-foot, and the stay-binding is passed up through the first and down through the second slot, as shown.

The Braider is represented in Fig. 3885. A piece of glass, of the form shown in Fig. 3886, is inserted in the presser-foot, and through a hole in this the braid is passed and thence conducted under the needle. The pattern is usually first stamped on the fabric.

The Tuck-Marker is represented in Fig. 3887. It is attached to the cloth-plate by a screw. The loose end of the connecting-rod j is inserted in the tube k. The gauge a is set as far from the needle as the width of the tuck is desired to be; and the end of the operating lever s is placed under the end of the needle-bar, with the end passing through the eyelet. The clamp-screw p on the gauge is then loosened, and the creaser g is set as far forward as it is desired to fold the cloth for the next tuck. The fabric is placed beneath the spring t.

The Seam-Trimmer.—Fig. 3888 represents an ingenious device for trimming seams of leather work. The knife D is attached to the trimmer-bar C. It is thrown out of action by means of the knob B, by which the rocker-shaft A is drawn forward, causing the knife to be lifted and held up by the spring. To set the blade in operation, the knob at the top of the trimmer-bar C is pressed down when the needle is at its highest point. Fig. 3889 represents the rolling presser-foot, which is preferable when leather is being stitched.

SHAFTING. Under this generic term is now included all that series of mechanism which is used to convey motion from the motor to the machine.

Shafts, once made of heavy timbers supported by iron gudgeons, are now replaced by light, polished iron bars, turned cylindrical and carefully straightened, to reduce friction to a minimum and to keep the rotating mass in perfect balance; and by the best makers they are also ground to standard gauges to insure a sufficiently uniform diameter. Shafts thus finished are known commercially by the size of bars from which they are made, but really measure one-sixteenth of an inch less in diameter (one-sixteenth of an inch, or by some makers one-tenth, being required for finishing). Some manufacturers, however, planish shafts by passing them through rolls, etc.; these shafts, known as *cold-rolled*, have an actual diameter equal to their nominal diameter.

Shafts, once sold by the pound, are now sold by the running foot, and the principal dealers keep a stock of the usual lengths ready finished on hand; these lengths are generally accommodated to the usual distances between the floor-beams in mills, and vary from 8 to 22 ft., the hangers generally being placed 7, 8, 9, 10, or sometimes even 11 ft. apart. This distance in a measure determines the diameter of the shaft to be used, a larger diameter being of course required to span the longer bays; for shafts are subject to two kinds of stress, the torsional one of transmitting power, and a lateral one between bearings, where the shaft acts as a beam fixed at both ends and deflected by gravity or by the pull of the belts. A shaft abundantly strong to resist the torsional stress if properly supported, may yet sag by its own weight between the bearings if these are not sufficiently close together. Hangers may be separated by from 6 to 9 ft. under ordinary circumstances. By diminishing the size of the shaft and increasing the number of bearings, we diminish the weight of the mass to be moved, and consequently its momentum and inertia and the resultant friction. Thus, for example, in cases where, from scarcity of water or other cause, it becomes necessary to economize to the greatest extent in the use of power, the very lightest shafts are employed, and hangers are placed at exceedingly close intervals, and even, in some cases, additional hangers of long drop are placed beside each pulley.

As rigidity between bearings is deemed so desirable, it is frequently obtained without materially increasing the journal-friction by employing large shafts, but reducing them at their bearings to a considerably smaller diameter. Thus a 6-inch shaft might be turned down for 4-inch bearings, and by this means the surface velocity of the journal, and consequently its tendency to heat, would be diminished; while the shoulders thus formed would abut against the boxes and prevent end motion of the shaft. In the absence of such diminished bearings, collars are used to prevent longitudinal motion in the bearings, and are either shrunk or welded on and turned up in place, or secured by set-screws. Collars should be placed at the ends of the same bearings, and not, as they are sometimes put, at opposite ends of the line of shafting. Differences in temperature will constantly alter the length of the line, and thus bring the collars too far apart or too close together. For example, in a line of 390 ft. (not an excessive length) the increment will be about one-thirty-second of an inch per degree F.; and a change from winter to summer—say from 40° to 98°—would increase the length of the line $1\frac{13}{16}$ inch; that is, if the collars were right in the winter, they would allow nearly 2 in. of end motion in midsummer, if they were at the outer ends of the boxes. Within recent years the speed of line-shafts, especially in cotton-mills, has been greatly increased, some mills running at as high as 400 revolutions per minute; but 300 and 200 revolutions are more common speeds. Machine-shop shafts should run at about 120 revolutions, while those for wood-working purposes run at about 240 revolutions.

In order to find the maximum torsional stress that may be transmitted by a shaft within good working limits, multiply the cube of the diameter in inches by 18.5 for cast iron, by 27.7 for wrought iron, or by 57.2 for steel. The product is the torsional stress in statical foot-pounds.

To find the diameter of a shaft capable of transmitting a given torsional stress within good working limits, divide the torsional stress in statical foot-pounds by 18.5 for cast iron, by 27.7 for wrought iron, or by 57.2 for steel. The cube root of the quotient is the diameter in inches. The torsional stress is expressed by the product of the actual torsional force in pounds by the radial distance in feet at which it is applied.

To find the maximum horse-power transmitted by a shaft within good working limits, multiply the cube of the diameter in inches by the speed in turns per minute, and divide by 285 for cast iron, by 190 for wrought iron, or by 92 for steel. The quotient is the horse-power.

To find the diameter of a shaft capable, within good working limits, of transmitting a given horse-

power, multiply the horse-power by 285 for cast iron, by 190 for wrought iron, or by 92 for steel, and divide by the speed in turns per minute. The cube root of the quotient is the diameter in inches.

To find the speed required for transmitting a given horse-power, multiply the horse-power by 285 for cast iron, by 190 for wrought iron, or by 92 for steel, and divide the product by the cube of the diameter in inches. The quotient is the speed in turns per minute.

Table showing Strength of Round Wrought-Iron Shafting (*Clark*).

DIAMETER OF SHAFT.	TORSIONAL ACTION.					TRANSVERSE ACTION.		
						Under the Gross Distributed Weight.		Under the Net Weight of Shaft.
	Ultimate Resistance.	Working Stress.	Work for One Turn per Minute.	Horse-Power at the Rate of One Turn per Minute.	Speed in Turns per Minute for One Horse-Power.	Distance of Bearings for the Limiting Deflection.	Gross Weight for the Span.	Distance of Bearings for the Limiting Deflection.
1	2	3	4	5	6	7	8	9
Inches.	Stat'l Ft. Tons.	Stat'l Ft. Lbs.	Ft. Lbs.	H. P.	Turns.	Feet.	Lbs.	Feet.
1	.42	27.7	174	.00526	190	6.6	30	7.9
1¼	.82	54.1	340	.01028	97.3	7.7	55	9.2
1½	1.42	93.5	587	.01779	56.2	8.6	89	10.3
1⅝	1.80	118.9	746	.02259	44.3	9.2	112	11.0
1¾	2.25	148.4	932	.02820	35.4	9.6	134	11.5
1⅞	2.77	182.6	1,147	.03469	28.8	10.1	168	12.1
2	3.36	221.6	1,391	.04211	23.7	10.5	198	12.7
2⅛	4.00	265.8	1,669	.05062	19.8	11.0	227	13.2
2¼	4.80	315.5	1,981	.05995	16.7	11.4	264	13.7
2⅜	5.62	371.1	2,330	.07051	14.2	11.8	305	14.2
2½	6.56	432.8	2,718	.08224	12.2	12.5	359	15.0
2¾	8.73	576.1	3,618	.1094	9.14	13.0	450	15.6
3	11.3	747.9	4,697	.1421	7.04	13.7	566	16.5
3¼	14.4	951.0	5,972	.1807	5.54	14.5	701	17.4
3½	18.0	1,188	7,458	.2257	4.43	15.2	854	18.3
3¾	22 1	1,461	9,178	.2775	3.60	16.0	1,029	19.2
4	26.9	1,773	11,136	.3368	2.97	16.7	1,225	20.1
4¼	32.2	2,127	13,345	.4040	2.48	17.4	1,439	20.9
4½	38.2	2,524	15,851	.4796	2.09	18.1	1,679	21.7
4¾	45.0	2,969	18,635	.5642	1.77	18.8	1,943	22.6
5	52.5	3,463	21,750	.6579	1.52	19.4	2,220	23.3
5¼	60.7	4,008	25,177	.7616	1.31	20.0	2,525	24.0
5½	69.8	4,609	28,936	.8758	1.14	20.6	2,854	24.7
5¾	79.8	5,266	33,077	1.000	1.00	21.2	3,210	25.4
6	90.6	5,983	37,584	1.137	.880	21.6	3,600	26.2
6½	117	7,606	47,780	1.445	.692	22.9	4,421	27.5
7	144	9,501	59,682	1.805	.554	24.2	5,426	29.0
7½	177	11,680	73,254	2.220	.450	25.3	6,518	30.4
8	215	14,180	89,088	2.694	.371	26.5	7,774	31.8
8½	258	17,010	106,886	3.232	.309	27.6	9,133	33.1
9	306	20,190	126,846	3.837	.261	28.7	10,650	34.4
9½	360	23,750	149,118	4.512	.222	29.8	12,320	35.7
10	420	27,700	174,000	5.260	.190	30.8	14,100	36.9
11	559	36,870	231,594	7.005	.143	32.8	18,180	39.4
12	725	47,860	300,672	9.095	.110	34.7	22,880	41.7
13	922	60,860	382,278	11.58	.0865	36.6	28,330	44.0
14	1,152	76,010	477,456	14.44	.0693	38.5	34,560	46.2
15	1,417	93,490	587,250	17.76	.0563	40.3	41,580	48.4
16	1,720	113,500	712,704	21.56	.0464	42.1	49,380	50.5
17	2,062	136,100	854,862	25.86	.0387	43.8	57,970	52.6
18	2,447	161,500	1,014,768	30.69	.0326	45.5	67,490	54.6
19	2,880	190,000	1,193,466	36.10	.0277	47.2	78,040	56.6
20	3,360	221,600	1,392,000	42.11	.0237	48.8	80,660	58.5

Note.—To find the corresponding values for shafts of cast iron or steel, multiply the tabular values by the following multipliers:

	2	3	4	5	6	7	8	9
Cast iron..	⅔	⅔	⅔	⅔	1.5	.86	.81	.86
Steel.....	1.2	2.06	2.06	2.06	.48	1.05	1.07	1.05

Frictional Resistance of Shafting.—The frictional resistance of horizontal shafting, running on cylindrical journals, has been determined by Morin and Webber. (See *Journal of the Franklin Institute*, lxviii., 261.) Taking the mean of the coefficients found by these investigators, the work absorbed by friction for one turn of a horizontal shaft with ordinary oiling is equal to .0182 $W d$, or with continuous oiling equal to .0112 $W d$. The horse-power absorbed by the friction of a horizontal shaft with ordinary oiling is represented by $\frac{W d S}{1800000}$, and with continuous oiling by $\frac{W d S}{2950000}$. In these formulas, W = total weight of shafting and pulleys, plus the resultant stress of belts in pounds; d = diameter in inches; and S = number of turns per minute. The resistance of upright shafting is probably about three-fourths of that of horizontal shafting.

Cold-Rolled Shafting.—Shafting made from wrought iron rolled cold has been introduced by Messrs. Jones & Laughlin of Pittsburgh, Pa., and has been proved by experiment to possess many advantages. A very full report covering all previous investigations has been made on the subject by Prof. R. H. Thurston, and is published by the manufacturers. Prof. Thurston's conclusions are: "1. The process of cold-rolling produces a very marked change in the physical properties of the

iron thus treated. (*a.*) It increases the tenacity from 25 to 40 per cent., and the resistance to transverse stress from 50 to 80 per cent. (*b.*) It elevates the elastic limits, under both tensile and transverse stresses, from 80 to 125 per cent. (*c.*) The modulus of elastic resilience is elevated from 200 to 400 per cent. The elastic resilience to transverse stress is augmented from 150 to 425 per cent.

"2. Cold-rolling also improves the metal in other respects. (*a.*) It gives the iron a smooth bright surface, absolutely free from the scale of black oxide unavoidably left when hot-rolled. (*b.*) It is made exactly to gauge, and for many purposes requires no further preparation. (*c.*) In working the metal the wear and tear of the tools are less than with hot-rolled iron, thus saving labor and expense in fitting. (*d.*) The cold-rolled iron resists stresses much more uniformly than does the untreated metal."

The structure is also rendered more dense and uniform. It is further stated that cold-rolled iron is suitable for all constructions not exposed to high temperatures; that it is especially suitable for all purposes demanding a high elastic limit and great shock-resisting power without permanent distortion; that the process improves the metal throughout—its benefit, as has been seen, reaching the centre of the bar, and rendering the whole much more homogeneous and uniform than common iron; and that in many cases it may prove superior even to some steels as a material of construction.

Table showing Strength of Hot-rolled and Cold-rolled Shafting (Thurston).

MATERIALS.	Shafts one foot long between Bearings, loaded at the middle.			Shafts fixed at one end, loaded at the other. Lever-arm, one foot.	
	Diameter.	Load.	Deflection per 100 lbs. of Load.	Load.	Deflection per 100 lbs. of Load.
	Inches.	Pounds.	Inches.	Pounds.	Inches.
Cold-rolled	$2\frac{7}{16}$	24,500	.00010	6,100	.00072
Hot-rolled	$3\frac{7}{16}$	18,000	.00012	2,250	.00095
Cold-rolled	2	18,000	.00018	8,250	.00144
Hot-rolled	$2\frac{1}{16}$	6,500	.00016	1,600	.00128
Cold-rolled	$1\frac{7}{16}$	8,150	.00098	780	.00744
Hot-rolled	$1\frac{5}{8}$	1,900	.00077	470	.00616
Cold-rolled	1	1,800	.0028	400	.02242
Hot-rolled	$1\frac{1}{16}$	1,050	.00218	200	.01944
Cold-rolled	$\frac{3}{4}$	[illegible]	.01762	90	.14250
Hot-rolled	$\frac{13}{16}$	250	.01447	[illegible]	.11562

The preceding table shows the relative strength of cold-rolled and hot-rolled shafting under the load to which the shaft may be repeatedly subjected without injury. If subjected to shock, however, only one-half of the figures in the table are allowable.

Works for Reference.—"A Manual of Rules, Tables, and Data for Mechanical Engineers," Clark, London and New York, 1877; "Mill-Gearing," Box, London, 1878; "Machinery and Mill-Work," Rankine, London, 1876. See also BELTING, COUPLINGS AND CLUTCHES, HANGERS, JOURNALS, and KEYS AND KEYWAYS.

SHAPING MACHINES FOR METAL. The shaping machine, or shaper, as it is more commonly termed in this country, may be regarded as a modified form of the planer, designed to act upon smaller surfaces. Its movements, notably in the quick return motion, correspond to those of the slotting machine; but the operation of the tools is the same as in the planer. For planing slots, keyways, etc., the shaping machine is better suited than the planer.

The Manville Shaper, constructed by the Hendey Machine Company of Wolcottville, Conn., is represented in Fig. 3890. The form shown has a stroke of 15 in. and cross-feed of 15 in., and will plane a piece 8 in. high. Its peculiar feature consists of a novel arrangement for producing a quick and accurate reversal of the cutter-bar for carrying the tool. For this purpose a double-faced friction-clutch is used, which is completely surrounded by two loose pulleys, running in opposite directions on the first pinion-shaft; the inner faces of the pulleys are turned to fit the exterior face of the clutch. The clutch has a longitudinal movement on the shaft, and is prevented from turning on the shaft by means of a fixed key, on which it moves endwise. To operate this clutch a hollow shaft is used, and in the hollow part a connecting-rod is so arranged as to connect the clutch with a shipping device. The clutch is connected with the rod by means of a pin passing through the hub of the clutch, also

through the shaft and rod. To allow the clutch to slide, a slot is cut in the shaft. On the opposite end of the rod, and between the pulleys and machine, is a so-called "cam-box," which works around a fixed stud secured to the main bearing of the machine. The cam-box has an annular groove turned in it, and is provided with a close-fitting ring which is secured in the cam-box by a cap screwed thereto. The ring revolves with the shaft, and is connected with the rod in the shaft by means of a pin, the same as described in operating the clutch. When the cam-box, with its revolving ring attached to the clutch by means of the rod in the hollow shaft, is caused to make a slight longitudinal movement, it imparts the same movement to the clutch on the shaft as the cam-box itself receives. For the purpose of obtaining this movement of the cam-box, a diagonal slot is cut in it, which works on the fixed stud; and by a slight revolving motion of the box is caused at the same time the end motion by which the clutch is moved. To accomplish this movement of the cam-box, a rod is connected with it and also with a sliding block on the side of the machine; this slide is so arranged as to receive its motion by means of the shipper-blocks, or stops, on the cutter-bar. These stops can be adjusted to any point on the cutter-bar, according to the length of stroke desired. The machine, being set in motion, is moving forward, or cutwise, until the stop on the cutter-slide strikes the sliding block on the side of the machine, causing it to traverse a short distance, and at the same time, causing a slight rotary and longitudinal movement of the cam-box by its connections as above described, moves the clutch, thus engaging one pulley, then the other, producing the reversing motion of the cutting tool as desired.

The Sellers Shaping Machine is shown in Fig. 3891. In this the upper surface of the bed or frame is provided with a flat slide, along which the head A traverses. Along the centre of the length of the slide is a screw operated by the handle B, which screw passes through a nut attached to the frame. The head A thus may be moved to operate upon any part of the slide. The latter reciprocates at a right angle to the length of the bed, and is operated as follows: The cone-pulley C communicates rotary motion to a shaft running along the entire length of the bed at the back. In the shaft

3892.

3893.

3894.

is cut a groove running from end to end, and upon it is a pinion having a feather fixed to the pinion and a sliding fit in the groove of the shaft or spindle, so that the pinion is rotated with the shaft, and yet may move along it. The pinion is held by the frame of the head and traverses with it, being in gear with the gear-wheel shown in the figure by an ingenious device to be hereafter explained Reciprocating motion is communicated from the gear-wheel to the slide or bar of the head. The work is fixed to the table or tables D, which are adjustable for height to suit the work, and which may be set at any required width apart upon the frame.

Fig. 3892 is a side view of the sliding head, showing at A the slide, D the connecting rod, and C the tool-holder.

We have now to describe the ingenious device above referred to, known as the Whitworth quick-return motion, which is shown in Figs. 3893 and 3894. Its object is to cause the slide, and hence the cutting tool, to travel faster during the return than during the cutting stroke, so as to increase the rate of working. Upon a convenient part of the head is placed a spur-wheel *A*, capable of revolving freely upon a fixed overhanging shaft of large diameter. Through this shaft, but not concentric with it, runs a spindle *C*, having upon its extremity a crank-piece *P*, which it keeps in contact with the face of the wheel. Thus supported, each would be able to revolve independently of the other—the wheel upon its fixed shaft, and the crank-piece round the axis of its spindle—but their revolutions would be eccentric to one another. But by slotting the crank-piece and fixing a pin in the face of the wheel, they are compelled to revolve together; the velocity of the crank, if that of the wheel be uniform, varying constantly, as the pin which drives it and the spindle which carries it approach and recede from each other. A dovetailed groove in the face of the crank-piece, at any part of which the end of the connecting-rod *R* can be set, provides the requisite adjustment for the length of the stroke. The arrangement of this device in connection with the Sellers machine is shown in Fig. 3895.

3894.

The counter-shaft of the machine shown is arranged with two speeds, one fast for narrow work, and one slow for a greater length of cut and for shaping steel. These differences of speed are in addition to the changes incident to the cone-pulley. The machines are provided with a spindle and chucking cones for doing circular work, such as planing up the bosses or hubs of rocker-arms; but in addition to this much work can be more conveniently held in independent centre-heads. Centre-heads are provided for each size of machine, with index-plates, carefully divided, and with tangent wheel and worm for feeding on circular work. The centre-heads are supported on a bar, so arranged as to be held in line or at right angles to the planer motion.

Hand-Shaping Machine.—Fig. 3896 represents a hand-shaping machine, the construction of which is clear from the engraving. The stroke is 6 in. vertical, adjustment of table 3 in., and length of traverse 8 in.

Shaper-Chuck.—Fig. 3897 is a chuck used in shaping machines and planers. *A* is the base, *B* the fixed jaw, and *C* the movable jaw. The work is placed between *C* and *B*, and is clamped by the jaw *C*, which is afterward forced toward *B* by the screws *F*.

Shaper or Planer Centres are attachments for holding work and rotating it over a given portion of a revolution. They are bolted to the work-table of the machine upon which they are used. In the Pratt & Whitney device, shown in Fig. 3898, *A* is a frame or bed carrying the heads *B* and *C*. The

work is placed between the centres D and E in the same manner as in a lathe. The dog or clamp fastened to the work is held in a fixed position in the driving piece at D by means of the set-screws shown. The method of moving the work through a given portion of a revolution is as follows: To the spindle to which the centre D and the holding device at B are attached is fixed the wheel F, the head B affording journal-bearing to the spindle. Around the circumference of F are cut teeth which mesh into the worm-screw shown. By operating the handle, which is attached to the spindle of the worm-screw, the wheel F is caused to revolve. On the outside face of F are drilled a series of circles of holes, each circle dividing the plate into a certain number of equal divisions, and into these holes a pin on the end of the spring-arm S fits.

3897.

Suppose that it is required to present the respective sides of a hexagon-shaped piece of work successively to the action of a planer or shaper tool. The arm S is set so that its pin end will stand in line with a circle of holes, the whole number of holes in which circle is divisible by 6 without leaving a remainder, and the pin-plate F is moved by the worm-screw until the projecting pin on the end of S falls into one of the holes of the circle. The cut is then taken on the work, and when finished the plate F is again moved by the worm-screw (or tangent screw, as it is also termed) until it has turned one-sixth of a revolution, when the pin will again coincide with a hole and enter it. If the circle selected contains 36 holes, then the pin will fall into every sixth hole; if it contains 48 holes, then into every eighth hole, and so on. The operator usually marks the hole in which the pin stands, and counts the necessary number of holes (as obtained by calculation) that the pin is to miss before entering another hole.

J. R. (in part).

SHEARING MACHINE. See CLOTH-FINISHING MACHINERY.

SHEARS. See PUNCHING AND SHEARING MACHINERY.

3899.

SHINGLE MACHINERY. Shingles are thin pieces or slabs of wood having parallel sides, but thicker at one end than the other, used for covering the roofs and sometimes the sides of houses. Shingles are usually 18 in. in length and have 6 in. of margin, termed the *gauge* of the shingle; the other two-thirds is cover. The excess over twice the gauge is the *lap* or *bond*. The material is first cut from the log, usually by drag-saws. (See SAWS.)

The Bolting and Sapping Machine made by Messrs. Snyder Bros. of Williamsport, Pa., is represented in Fig. 3899. The block as cut by the drag-saw is placed endwise on the carriage, and the sap-wood is taken off. It is then placed with the centre on the small point shown at the middle of the carriage, and is sawn into bolts. This machine has an iron frame, and by its aid it is claimed that one man can bolt and sap up to 100,000 shingles daily.

3900.

Shingle-sawing Machines cut the bolts up into shingles. Fig. 3900 represents the improved Parker shingle-sawing machine, made by the manufacturers above named The circular saw and jointer are in the same frame. The block is held by spiked rolls in a carriage which presents the bolt, butts, and points alternately The saw used has a diameter of twice the length of the shingle to be sawed, and the block is presented sideways to the saw, so that the cuts of the teeth are nearly parallel with the fibres of the wood. Among the advantages claimed for this machine are, that with it a long or 30-inch shingle can be cut with a 30-inch saw, and it can be adjusted to cut shingles of various lengths from 14 to 30 in. The thickness of

the shingle can be increased at pleasure, and round timber can be sawed as well as square or flat. The manufacturers state that one man can saw and joint, as a regular day's work with the machine, 15,000 shingles 18 in. long.

Fig. 3901 represents a horizontal shingle-sawing machine made by Messrs. Trevor & Co. of Lockport, N. Y. In this the saw is horizontal and the carriage reciprocates over it, the shingles being delivered upon a slide under the machine as shown.

Fig. 3902 represents Evarts's patent 12-block shingle machine, manufactured by Messrs. C. S. & S. Burt of Dunleith, Ill. Upon each of two sides of a frame about 7 ft. square is placed an upright shaft. These shafts each carry a horizontal saw, and above the saws a circular carriage is mounted. The

3902.

carriage is divided into 12 spaces, into each of which a block to be cut into shingles is placed while the carriage is in motion, new blocks being supplied as fast as the first ones are cut up by the saws. The carriage is driven by friction-rollers. The dogs are simply weights raised by an inclined plane, to drop off the end and fasten the block while the saw is passing through. It is claimed that this machine will produce from 130,000 to 150,000 shingles per day.

Fig. 3903 is Brown's spalt and shingle machine, intended to utilize lumber, such as thick slabs, log-buttings, board-trimmings, and other material, which usually constitutes the waste of saw-mills. The wood is clamped on the carriage, which can be moved longitudinally to present the work to the saw, and transversely to feed after each successive cut.

Shingle-cutting Machine.—Fig. 3904 represents a machine made by Messrs. Trevor & Co. of Lockport, N. Y., for cutting shingles from steamed bolts. The shingles are cut by the large reciprocating knife shown, which is operated by a [illegible]

3904.

[illegible] upper end of an upright rod, welded to a short arm shown in the engraving at the end of the table. This machine is claimed to cut 40,000 shingles per day.

SHOE-MAKING MACHINERY. A large number of machines have been devised to supplant hand-labor in the manufacture of boots and shoes. In the American modern shoe factory the division of labor on the various parts of the shoe is carried to its greatest extent. The following résumé of the various manipulations will indicate the many processes through which the leather passes while being made up into a finished shoe, and at the same time will show the order of use of the machines hereafter noted in detail. Shoe-sewing machines, which are among the most important of shoe-making machines, will be found described under SEWING MACHINES.

3905.

In the shoe factory, the uppers and linings of a shoe are stitched generally in one department, where the buttonholes are worked by hand or by a machine especially adapted to that purpose, and the buttons put on or eyelets punched, if for a laced shoe. The uppers being ready, the first process in bottoming is to wet the soles, which, after being partially dried, are passed under a heavy roller, which takes the place of the shoemaker's lapstone. They are then, if for machine-sewing, after being properly cut out for the requisite sizes, run through a channeling machine, which takes out a thread of leather from the outside edge in the bottom of the sole, leaving a thin narrow flap all round, so that when the stitch is laid in the place of the leather thus removed the bottom may be hammered down so smoothly as hardly to indicate where its surface was raised to allow of the stitching. The upper is then drawn over the last and tacked on the insole, and the outsole is tacked on. The last is now withdrawn, and the shoe passed to the sewing machine, where the stitch is made through the outsole and insole, and the edge of the upper coming between them, the flap raised for the channel being laid and cemented over the seam. The heel is now put on in the rough, and the edges of both heel and sole are trimmed and burnished. In making a "turn" shoe, the sole is shaped before tacking to the last, on which it is placed with the grain side of the leather, or that which is to form the bottom of the shoe, next the last; the upper, with the stiffening in, is then pulled over, wrong side out, then lasted and sewed, the last being taken out after sewing, and the surplus upper cut away. The shoe is then turned right side out, first at the seat, then the ball and toe, the last again put in, and the sole and stiffening hammered into proper form. A "team" of

3906.

shoemakers consists of from four to nine men, comprising lasters, heelers, trimmers, burnishers, and finishers, who complete the shoe, after the uppers are made and the soles cut out. But the number of men in a team and the way in which the work is divided up are altogether dependent upon the kind of work.

MACHINES FOR WORKING THE LEATHER.

The Power Roller of ordinary form is represented in Fig. 3905. Its object is to compress and harden the leather by passing the same through heavily-geared rolls, as shown.

The Sole-cutting Machine is represented in Fig. 3906. The bed of this machine consists of a number of blocks of hard wood bolted together and supported by a heavy iron frame. Above the bed there is a heavy iron beam having guide-rods which extend downward through suitable boxes at the ends of the main frame. In the lower part of the frame a heavy shaft is journaled, which carries two eccentrics (one at each end), whose rods are connected with the ends of the iron beam. The main shaft is geared at both ends to relieve it from torsional strain. A side or piece of sole leather is placed upon the bed, and dies having the form of the soles to be cut are placed upon the leather. The shaft is then allowed to rotate, when the beam will be forced down upon the dies and the leather will be cut

Sole-moulding Machine.—Fig. 3907 represents the power sole-moulding machine made by Messrs. Swain, Fuller & Co., of Lynn, Mass. This apparatus is used to mould the sole to fit the bottom of the last. The lower platen is forced against the upper one by the powerful gearing shown in connection with a knee-joint, and is thrown back by means of coiled springs when the pressure is removed.

The Skiving Machine is used for skiving or paring leather down to any desired width of scarf. In Tripp's counter-skiver, represented in Fig. 3908, the knife is held by steel gauges at each side of the edge, and is adjusted to any thickness of stock by an automatic feed-roll. A rand is produced from any thickness of stock by the

3907.

same movement. For this purpose a blade is arranged to strip the stock as the rands are split.

Rand-forming Machine.—A rand is one of the slips of leather placed beneath the heel of a sole to bring the rounding surface to a level, ready to receive the lifts or pieces of sole leather with which the heel is built up. In the machine represented in Fig. 3909, the rand-strip is passed in at the orifice *A*, and is seized between two steel formers, one of which is held up against it by the central shaft, around which it is bent as its thin edge is crimped by the formers. The strip is kept in a curved path by a guide, and is released by a stripper at the lower opening *B*, properly crimped and curved.

MACHINES FOR JOINING THE PARTS OF THE SHOE.

The Pegger.—The essential parts of this machine are as follows: 1. An awl driven upward and downward by suitable mechanism; 2. A peg-driver, raised by a cam and preferably driven down by a spring; 3. A feed to move the shoe the distance between the holes into which the pegs are driven, which feed-motion may be given to the shoe either by the awl moving bodily sideways while in the leather and carrying the shoe with it, or by a rotary feed-wheel, the first being preferable; 4. A strip of peg-wood arranged to be fed under the peg-driver at the moment the driver is elevated over a hole previously formed by the awl; 5. A splitter or cutter to separate the peg from the strip; 6. Means of regulating the feed of the shoe; 7. A jack to hold the shoe with the bottom of the sole upward, and under the driver and awl, so constructed as to enable the angle at which the pegs are driven into the sole to be adjusted slightly, and also so constructed as to allow for the variation from a horizontal plane of the bottom of the shoe; 8. A guide against which the side of the shoe-sole rests, and which regulates the distance of the line of pegging from the edge of the sole. This guide is usually made adjustable. The jack serves as an anvil, and hence must be strong and firm. Machines for pegging two rows are simply double apparatus of the above class.

The most important feature of the invention is the strip of peg-wood, to produce which a whole series of ingenious contrivances are employed. A peculiar lathe cuts it from a round log in a long spiral ribbon. This being very tender and delicate, another special machine is employed to wind it up. There is a peculiar process of drying and seasoning. Another machine points and bevels the edge so as to make the pegs pointed. As it is essential always to have the bevel at a certain angle, Mr. B. F. Sturtevant (the inventor of these devices) contrived a machine to grind the knives of the sharpener so as to keep the same angle on them, that they might always cut the same way. Lastly, a machine for compressing the pegs was invented. The construction of

3910.

the peg-strip as above described will be readily understood from Fig. 3910. About 900 pegs are inserted per minute. The peg-strip measures about 100 ft. in length, and on an average there is 22 in. of pegging in a shoe. From 4 to 6 pegs per inch are commonly driven in, but there is a great variety of sizes of peg-wood for different shoes, and some shoes are pegged in double rows.

The mechanism of the "Champion" pegger, represented in Fig. 3911, is easily followed. The long jack-standard *A* is hinged by a universal joint to the foot-lever, which is weighted at one end to hold the shoe in contact with the feeding devices, and at the other with a foot-rest to disengage the finished shoe. The jack is capable of lateral and longitudinal motions upon the standard, to present the surface of the sole at the point of contact with the pegging devices in a horizontal plane. The vertical plunger, carrying an awl and a driver, is operated by a cam and gearing and a spring. The rotary feed is immediately back of the peg-guide, and is operated by a pawl and ratchet receiving motion from the main gearing, usually by a cam. The peg-strip is fed into the guide from a core, and a peg is cut off by a lateral knife at each fall of the driver, immediately before being driven into the shoe.

The Wire-screwing Machine connects the soles by the insertion of bits of screw-threaded wire. The wire is taken from a coil, which rotates bodily in a horizontal plane while unwinding, and thus screws the wire into a die, which while cutting the thread upon it causes the wire to move downward and into the shoe. A knife suitably adjusted cuts off the wire at proper length.

For shoe-sewing machines, see SEWING MACHINES.

MACHINES FOR FINISHING THE SHOE.

The Seam-Rubber is represented in Fig. 3912. The shoe is placed on the stationary arm of the machine, and the metal disk, pressed down by the spring shown, is rubbed over the seam to smooth and flatten it.

3912.

The Beating-out Machine is used for beating out the soles after the upper is sewed on, thus closing the channel in which the stitching is made. Fig. 3913 represents the "American" machine made by Messrs. Swain, Fuller & Co., of Lynn, Mass. The shoe is placed upon the last, and the mould is caused to descend upon the sole with great force, thus both pressing the sole and laying the channel. The pressure is given by the treadle, which brings the upper platen down upon the sole. The treadle is then locked down, and the workman adjusts another shoe on the second last, shown on the carriage, before removing the pressure from the first sole. By the use of this machine it is claimed that one man can do the work of three using ordinary hand-hammers.

The Shoe-Heel Trimmer.—Fig. 3914 represents the Coté shoe-heel trimmer, the use of which is indicated by the name. The shoe is held stationary by the treadle-clamp, and the knife-stock, which is centrally pivoted to the outer plate or jaw bearing upon the tread-lift, is then grasped in the hands of the operator and moved to give a sweeping cut to trim the heel

Keen's heel-trimmer is represented in Fig. 3915. The shoe is held by a clamp as before, and the trimming knife is operated by means of the crank shown. In the machine which is used for trim-

3914.

ming edges the shoe is mounted upon a jack, the carriage of which has communicated to it a movement of translation and rotation, so that while the side of the sole is being trimmed, the shoe is fed longitudinally against the knife, but at the toe and heel is rotated beneath it. The knife

3916.

3917 represents a self-feeding eyelet machine, which places and fastens metallic eyelets in punched holes. The eyelets are placed in the receiver on top, and are fed down the channel. At the bottom they pass between the plunger and anvil, and

are riveted in their places in the shoe or strip of leather, which is held and fed by the operator. Figs. 3918 and 3919 represent two forms of punches. Fig. 3918 is the common punch and eyeletter,

3917.

3918.

3919.

forced down by foot-pressure and retracted by a spring; and Fig. 3919 is a self-feeding punch, which feeds the leather and punches the holes any distance apart for the eyelets.

SHUTTLE. See Looms, and Sewing Machines.

SIGNALS, RAILROAD. Devices for securing safety upon railroads by communicating intelligence between persons in charge of the train and those in charge of the roadway, or, as in the case of automatic signals, between two trains following one another. Signals are usually constructed as signs erected alongside the track, which, according to change of their position, form, or color, convey instructions to the engine-driver. They may be divided into switch signals, which show whether the switch is set for the main line or for a side track, and road signals, which indicate whether the line ahead is or is not clear. Besides these, there are numerous other signals used in railway traffic. Posts beside the track indicate distances, grades of the road, and special orders at certain places for the engine to stop, whistle, etc. Cautionary signals are used to warn brakemen on the tops of freight cars of proximity of low bridges, these devices being simply series of wires or ropes suspended from cross-rods, which come in contact with the brakeman's person as the cars pass beneath them. Torpedoes are placed on the track some distance in rear of a train accidentally delayed, to warn following trains; and the approach of trains to stations or crossings is sometimes announced by electric bells automatically operated by the passage of the engine and cars over certain parts of the track. Communication between the cars and the engine is effected by a bell-rope. The engine-driver, when hand-brakes are used, signals instructions to the brakemen by blasts of the whistle. Flags or lights of different colors are used on moving trains to indicate that other trains are following, etc.

In the early days of railroads, when the trains were few and separated from each other by a long interval of time, no special signaling apparatus was used. The signals were given in daytime by a flag held or waved horizontally or vertically, and at night by lanterns of different colors. These primitive methods are still used when switching trains in depot yards. At the present time signals exist in many varieties.

The Switch Signal shows the position of the switch. In Fig. 3920 is represented one form of switch signal which is extensively used in this country. The round target *A*, at right angles to the line of the track, being visible from the train, shows that the switch is placed for the siding. If the target *B* is presented to view, it means that the switch is placed for the main line. These two targets (being relatively at right angles to each other) are attached to a vertical shaft, which ends at the bottom with a crank acting on the switch. By means of a hand-lever *L*, the shaft, which is fastened on an iron stand, can be turned over an angle of 90°, moving the switch and exposing the one or the other target. The round target is usually painted red and the other one white, to insure a distinct difference between them. At night, the position of the switch is shown by the red or white light of the lamp placed on the top of the shaft. For a three-throw switch the shaft is turned 90° to move the switch from one extreme to the middle track, and again 90° to move it to the other track, thus making in the whole 180° or half a revolution. One of the targets is then exposed twice to view, namely, whenever the switch is set for the outside tracks. To indicate for which of the two tracks (right or left of the main line) it is set, the form of the target is not made symmetrical in regard to its centre-line. One half may be made pointed (an arrow form is used sometimes), the point indicating for which of the side tracks the switch is set.

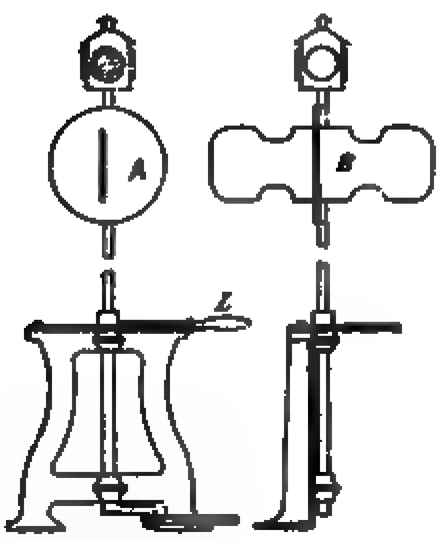
The simplest form of a switch signal is a target attached to the top of an ordinary reversing lever which moves the switch. The position of the lever, whether to the right- or left-hand side of the central (vertical) position, indicates the position of the switch.

Road Signals show whether the road ahead is clear, and include "safety," "danger," and "proceed

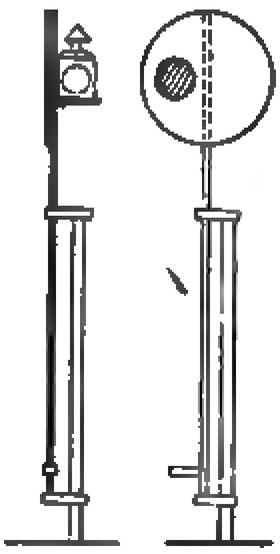
with caution" signals. Of these there are three principal kinds, namely, the "disk signal," the "semaphore signal," and the "optical signal." The optical signal conveys intelligence by exhibiting different colors. These are difficult to distinguish at a distance; and since it has been proved that "color-blindness" is alarmingly frequent among railway employees, they are being slowly abandoned.

The Disk Signal is represented in Fig. 3921. It is a round target, usually painted red on the side which is to be observed (separate signals being used for each line of a double-track railroad). When

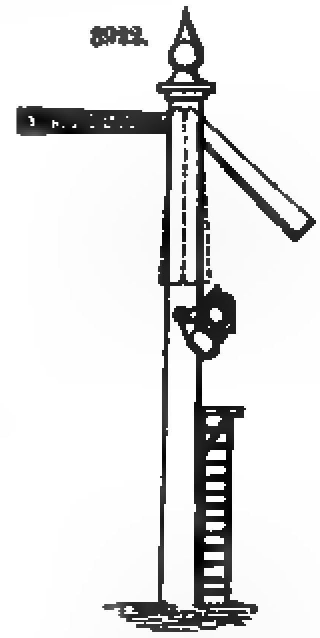
3920.



3921.



3922.



placed in view with its face toward the approaching train, it means "danger"; and when concealed—that is, placed parallel with the track—it indicates safety. A lamp placed behind the disk shows a red light for danger at night. To make this signal positive in both its positions, it is now customary to attach to the shaft another disk of different color, or a differently shaped target, at right angles to the first disk and below it, which when exposed indicates "safety." A signal will then be visible whichever way it be set.

The Semaphore Signal, shown in Fig. 3922, is considered by many to be the most conspicuous, and is rapidly being introduced in preference to other types, especially in Europe. It consists of a high post, to the top of which one or more arms are pivoted, moving in a vertical plane. Signals are given by the different positions of these arms, which are arranged to move through a quarter of a circle. If the arm hangs vertically (as shown in dotted lines), it means "safety"; if it is raised horizontal, it signifies "danger"; and if placed at an angle of 45°, "caution." If only the first two signals are used in the system, the position of the arm at 45° is often taken for "safety." This is a preferable arrangement, as both the signals are then positive.

3923.

Signaling at night is accomplished by means of a lamp which is attached to the post, and in front of which a pair of "spectacles," containing red and green glasses, are moved by means of the same rod which operates the arm. The red, green, and white lights indicate, respectively, "danger," "caution," and "safety."

Arms are sometimes placed on opposite sides of semaphore-posts to convey signals to different tracks. Thus, in England, when the train is running on the left-hand track, the driver observes only the arms on the left-hand side of the post, whether this track be the up or the down line. In the United States the case is just the opposite. On junctions where there are many tracks, and an arm for each track has to be attached to the same post, these are placed one below the other, but always on the same side of the post for the tracks leading in the same direction. The semaphore-arms are usually painted in different colors on the two sides.

Optical Signals are those which convey intelligence by exhibiting different colors. The apparatus consists of a box as shown on the outside of the second story of the signal house, Fig 3923. In the lower portion of the box, on each side, are circular openings, 20 in. in diameter, covered with ordinary glass. Apparatus exists within the box by which red or green targets or lights may be shown at will. Each side of the apparatus gives signals for one of the two tracks. The attendant gets a distant view on the line from the upper story of the house, and finds in it a comfortable shelter.

Acoustic or Audible Signals are often a valuable addition to the signals of the other types in case of storm or fog, when the latter may not be seen, or may be easily mistaken. For this purpose, on

some roads, at the bottom of a shaft which supports the disks is attached an arm, with a torpedo at its end. This arm swings simultaneously with the disk. If the disk stands at "danger," that is, perpendicularly to the line, the torpedo is placed on the top of the rail. The next train passing causes an explosion of the torpedo, and thus receives warning.

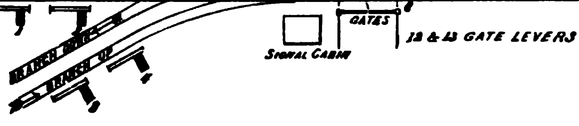
Another way of giving audible signal is by acting on the steam-whistle of the passing locomotive. This is accomplished either mechanically or electrically. In the first case a lever connected with the signal acts on a lever attached to the locomotive whistle, opening its valve. The electric device is an invention of M. Lartigue, and has been successfully used on the Northern Railroad of France. It is also employed in connection with the vacuum-brake. (See BRAKES.)

"*Distant*" *and* "*Home*" *Signals.*—One signal is not enough to protect a train stopped at a station from following trains, for the reason that the engine-driver of the latter may often be unable to bring his train to a standstill after discerning the signal before it comes in collision with the train ahead. Even if the second train should stop near the signal, during its delay it would be unprotected from succeeding trains. To obviate these difficulties, in addition to a signal near the station termed the "home" signal, another called the "distant" signal is established at an interval of from a quarter to half a mile from it. The distant signal shows the position of the home signal. On sighting a distant signal at danger, the driver stops his train at once, and then proceeds past the signal far enough to protect his train from the rear by the distant signal. He then awaits the movement of the home signal. As the position of the distant signal often cannot be well seen by the home-signal man, devices called "repeaters" are placed in the signal cabin. These are usually miniature signals which are moved by wires from the distant signals to the position of the latter. To distinguish night signals, in the back of the lamp is made a small opening called "back-light," which faces the signalman's cabin. Small frames or spectacles, similar to those used in front of the lamp, and moving with them, are placed behind the "back-light," thus showing which of the signals is exhibited. An electric device is also used, which enables the signalman in his cabin to know whether the light in the lamp is burning or extinguished.

INTERLOCKING SIGNALS.—The idea of concentrating at convenient points the levers by which numerous signals and switches are worked was advanced in the early days of railroading. The advantages promised were reduction in the number of attendants and in working expenses. On the other hand, difficulties in the possibility of making mistakes between levers, etc., soon became apparent, and outweighed the benefits. To obviate these difficulties, the "interlocking" system was devised. To understand the principle of this, the simplest case of meeting tracks must first be considered. This is that of a simple junction which two trains may approach in the same direction, one being on the main, the other on the branch line, or from opposite directions. Under these circumstances, it would be impossible with the interlocking system to give both trains a safety signal—the result of which would be collision—for the reason that, while the signal to one train shows "safety," it can be so set only after showing "danger" to the other train. Nor could the "danger" signal be withdrawn until the first or safety signal was placed at "danger." On a more complicated junction, the number of combinations being greater, the danger of mistakes would be still increased. If a train, before arriving at such junction, crosses one or more tracks, all these tracks, including those from which it starts and on which it is to arrive, should be closed to other trains; and these tracks are then in a condition which is technically called "fouled." The danger of setting a signal to safety, for a train proceeding to or from the branch, before the switch is moved in the proper position (which is not an unknown cause of accident), has also been provided against by the interlocking system. Not only, moreover, does the latter require the switch to be moved in due time for the train to shift, but the switch must be caused to traverse its full throw (set "home"), and be locked in this position. On safety or point switches, placed so that the trains run over them in the direction toward which the switches are pointing, switch-locks are not needed, as the trains will force their way on the main line. (See "Safety-Switches," in the article RAILROAD.) The working of gates at a roadway crossing or draws of bridges can be made in a similar manner dependent on the relative positions of signals.

Fig. 3924 represents a double junction, and shows the disposition of the interlocking system. This will serve as a model from which plans for operating more complicated junctions may be easily arranged. The levers in the signal cabin, of which there are thirteen, are all numbered to correspond with the plan. Nos. 1 and 2 are respectively the distant and the home signals for the "main up line"; Nos. 11 and 9 are the same for the "main down line"; Nos. 11 and 10 are the same for the "branch down line"; Nos. 3 and 4 are the same for the "branch up line." No. 5 is the switch for the "branch down line,"

3924.



and No. 7 the lock for this switch; No. 6 is the switch for the "branch up line," which has no lock for the reason already stated. Nos. 8, 8 are the cross-over track, which is provided, in order to avoid confusion, with the ordinary switch targets. Nos. 12 and 13 are levers operating the gates. In this plan there is only one distant signal, No. 11, for the "main down" and "branch down" lines.

Normally, all signals are set at "danger," the switches are opened, the main lines unbroken, and the gates closed against the roadway traffic. In this position nothing interferes with the movement of trains on both of the main lines; their signals are consequently unlocked, and may be lowered to "safety" for an approaching train. But signals of the branch lines are locked at "danger" as a con-

sequence of the switches being open. A movement of any of the levers will now produce locking and unlocking of other levers. The different cases are as follows: *a.* Moving to safety of the signal No. 9 locks the lever No. 7 in its normal position, preventing the switch from being set for the "down branch" line. The distant signal No. 11, showing only the condition of the home signal, does not open the passage over the junction, and consequently does not interlock with the switch. *b.* Signal No. 2, when moved to safety, locks the switch No. 6 in its normal position. *c.* When a train is to pass from the main down to the branch down line, and nothing interferes with its passage, the switch-lock lever No. 7 is reversed, which action, unlocking the switch, will lock the signals Nos. 2, 1, 9, and 10. The switch-lever No. 5 is next reversed, setting the switch for the branch and unlocking signal No. 10, which is, however, still locked by the lever No. 7. Until this lever is reversed to its former position, when the switch-lock locks the switch again, the signal No. 10 cannot be set to safety. During the whole operation nothing prevents the attendant from admitting trains from the branch up to the main up line. *d.* If a branch-up-line train has to pass the junction, the switch-lever No. 6 is reversed, setting the switch, locking signals Nos. 1 and 2 at danger, and unlocking signals Nos. 3 and 4, which are then set to safety by reversing their respective levers. This operation does not interfere with the traffic on the main down and the branch down lines. *e.* The cross-over track, if set to effect a junction between the two lines, locks all the signals at danger. *f.* If all signals are at danger, the gates can be opened for the roadway crossing, by reversing first the stop-lever No. 12, which action locks all signals, and releases the gate from the "stops" which prevent the gates from being opened by any one except the attendant. The gate-lever No. 13 is next reversed, moving all four gates open, and also locking the signals. The gates in their new position are held by another pair of stops. To move back the gates, the levers are changed to their former position, the signals being locked until the gate is closed. Gates cannot be opened for the roadway crossing if any of the signals indicates safety, the gate-stop lever being then locked by the signal-lever.

The Saxby and Farmer Interlocking System is one of the best known forms of this apparatus. Its mechanism is shown in Figs. 3925, 3926, and 3927. A series of levers is placed side by side in a cast-iron floor-frame. Two of the levers are shown in Fig. 3925, one in a normal position, the other in an intermediate position. The levers are bent and pivoted at *P*, and their short horizontal arms are connected by means of rods and bell-cranks with the switches or signals.

In order to counteract the expansion and contraction of the long rods caused by differences of temperature, a compensating lever is used, consisting of a straight bar pivoted in the centre, which divides the whole rod in halves. Each half of the rod connects with the opposite end of the lever. When the rods expand, they move the lever a corresponding distance around its centre, so that neither signals nor signal-levers are affected.

The levers move in quadrants, which are arched, vertical ribs, cast on the frame. At the end of each quadrant is a notch in which enters the latch or "catch" of a spring catch-rod, with which each lever is provided, as shown in the figure. The distance between the notches is the whole throw of the levers. To reverse a lever, the catch must first be lifted from its notch, and this movement of the catch is utilized here for the locking or unlocking of other levers. This is accomplished as follows: A sliding block *B*, Fig. 3925, is attached sideways to the catch, by means of a stud. This block is placed in a curved slot of a rocker *D*, in which it can slide, and which is pivoted in the centre at *A*. When the lever is in its normal position, the catch is lowered in the notch of the quadrant, and consequently the block *B* presses the corresponding end of the rocker down, raising its other end; and when the catch is lifted up from the notch of the quadrant, it raises the depressed end of the rocker, placing the latter in a horizontal position. While the lever is being reversed (see the nearest lever with its rocker in Fig. 3925), the block *B* slides in the rocker without affecting its position, as the slot in the rocker is curved in an arc of a circle from the centre *P*; but when, at the end of its throw, the catch is lowered into the corresponding notch, it depresses the other end of the rocker, which will take a position the reverse of its first one. The left-hand end of the rocker is connected by a universal joint with a vertical connecting-rod *E*, which acts on the crank of a spindle *G G*. The central portion of this spindle is flat, and when in normal position is horizontal. In Fig. 3925 one half of the spindle is shown in horizontal position at *H*, the other in vertical position at *I*. The mechanism above described is applied to each of the levers. Above the spindles *G G* are placed locking bars shown in cross-section in Fig. 3925. Each lever which locks other levers has such a locking bar, and these bars can be moved in the direction of their length, which movement is effected by the motion of the spindle. This will be more clearly understood from Fig. 3926, which is a side view of the apparatus (levers and rockers being detached). Only the first spindle to the left is shown with its crank and the connecting-rod

E; the other spindles, *M* and *N*, are shown in cross-section. Above the spindles is the locking bar which is moved by the first spindle, by means of a casting *K*, which is riveted to the bar, and which engages with a stud of the spindle. When the spindle turns on its axis this stud pushes the locking bar. The locking bar carries locks *L L*, which move with it, and which, according as they do or do not fall in the way of a spindle, prevent the latter from being turned on its axis, or the reverse. Referring to Fig. 3926, the spindle *N* cannot be turned, while the spindle *M* can be, the first being locked and the other unlocked. It will be found, by following the movements of the different parts of the apparatus, that when a spindle is locked its respective lever is also locked, and thus it cannot be reversed. The spindles are also provided with holes as seen in Fig. 3925 at *I*. If a lock is placed directly above a hole, the spindle will not be locked. This is shown at *N* in Fig. 3927.

By considering now three different positions of the spindle, which correspond with the positions of the rocker, the operation of the mechanism will be easily understood. The first position of the spindle (normal) is horizontal, as shown on the left-hand end spindle in Fig. 3926; the third position of the spindle is shown at *O* in Fig. 3927; and the second position is intermediate between the first and third. In the first position, Fig. 3926, some of the spindles are locked, as at *N*, and others are unlocked, as at *M*. In the second position, the locking bar, being partly moved in the direction of the arrow, will lock the spindle *M*, but the spindle *N* will not be unlocked, as the lock has not moved far enough to meet the hole in the spindle. This last is, however, attained in the third position, as shown in Fig. 3927. It will also be noticed that the locking bar, arriving at the third position, becomes itself locked by the spindle *N*, provided the latter has been moved from its normal position by reversing its corresponding lever; and that therefore the first spindle, and thus its corresponding lever, cannot be brought back to its normal position until the spindle *N* is first placed normal. This counterlocking of the first spindle in the third position is very important in the system. Suppose, for instance, that the first spindle is acted on by a signal lever, and the third spindle by a switch lever: it is obvious that to move the switch the signal must be first set to danger, and that the signal cannot be restored to safety until the switch is first moved to its normal position. With these means any amount of combinations can be made, and, no matter how complicated be the junction, a perfect interlocking system can be applied to it.

The Toucey and Buchanan interlocking apparatus, used in this country, differs from the foregoing only in details of mechanism.

Interlocking has also been effected by pneumatic means. On the Old Colony Railroad, at Boston, a draw-bridge signal is interlocked with the lock of the bridge by means of air inclosed in a pipe, which, by being either compressed or expanded, moves the signal. Interlocking by means of electricity is used in connection with the "block system."

Systems of Operating Signals.—*a. The Time System.*—A certain interval of time must elapse between the departure of two successive trains from a station. The time varies on different roads, and according to the different speeds at which the trains travel. Generally from 5 to 15 minutes is accorded for safety. Less time is required if the first train travels faster than the succeeding one, and *vice versa*. If, therefore, a train passes a signal, that signal is set behind it at danger, and the attendant at the expiration of the specified interval of time opens the line by restoring the signal to safety. It is obvious that such a system can insure safety only when all trains travel at their proper speed, and when nothing happens that may arrest their movement between the signal stations.

b. The Block System.—The imperfections of the time system are successfully remedied by the substitution of an interval of distance for the interval of time. This constitutes the "block system." In its operation the line is divided by signals into distances, called "sections"; and the essential principle of the system is, that only one train at a time is allowed upon a section. To insure this, the signalman stationed at one end of a section must, of course, know whether any train is or is not upon that section. Hence there must be telegraphic communication between the signalmen.

The block system is applied in two different ways: as the *absolute block system*, in which, if a train occupies a section, that section is blocked, and another train cannot enter on it; and as the *permissive block system*, which is less perfect than the other, as in this the following trains may enter a section already occupied, though receiving cautionary signals. On some roads the time system is combined with the block system, all trains entering on a blocked section being detained for a few minutes before cautionary signals are given.

The apparatus used in working the block system is in both cases alike. It can be divided into two classes: 1. Mechanism independent of the road signals, and serving as a means of transmitting intelligence between the neighboring signal posts; 2. Mechanism which acts directly on the road signals. The second class is subdivided into (*a*) apparatus which requires the presence of attendants, by whom it is manipulated, and (*b*) apparatus which is operated by the movement of the trains, and which is thus automatic.

1. *Mechanism independent of Road Signals.*—To this class belong the devices of Cooke, Walker, Tyer, Preece, Regnault, and some others, and the "electric-slot signal," which, as will be shown, is a distinct form, combining the interlocking with the block system. These contrivances are either acoustic or optical. In either case the signal stations are connected by telegraphic wires, one for each line, and each station has an apparatus which communicates with the neighboring station. An acoustic apparatus is simply an electric bell, on which, according to the different number of strokes, different signals are given. The attendant has no power over the bells at his station, which can be actuated only from the neighboring stations; but he has two keys (circuit-closers) with which he in turn can work the bells of other stations. The working of the system, taking the simplest bell code, is as follows: Let *A*, *B*, and *C*, Fig. 3928, designate three successive stations. Suppose a train to enter upon section *A B*. The signalman at *A* presses

3928.

the key twice in succession, giving two strokes on one of the bells at *B*, which signal is merely a question from *A* to *B* whether the train may enter the section. If *B* answers affirmatively by two strokes on the bell at *A*, *A* starts the train by giving it the outdoor safety signal, and at the same time sounds the bell at *B* to announce the fact that he has done so. *B* acknowledges this by returning two strokes on the bell at *A*. When the train has reached *B*, the attendant there gives three strokes on the bell at *A*, to announce that the train has arrived; and in acknowledgment of this *A* strikes three times the bell at *B*. The operation is repeated between *B* and *C*, and so on. The bell code is more complicated if the description of the kind of train or other intelligence is to be transmitted.

The *optical apparatus* is an improvement on the acoustic system, in that the signals after being made are lasting, until the time for changing them again arrives. Electric bells are also here used, but only to announce a change in the signals.

These signals are made by the deflection of a magnetic needle to the right or left from the vertical or neutral position. In one position the needle points to "Line Clear," in the other to "Train on Line"—words which are inscribed on the dial of the instrument.

Tyer's instrument is provided with two needles for each line, which for distinction are differently painted. One of the needles shows the last signal received, the other the last signal sent.

Regnault has improved this instrument by arranging it so that the message sent is automatically repeated at the instrument of the sender, announcing its receipt, without any action of the receiver. The action is here as follows: If the attendant at *A* has to announce a train at *B*, Fig. 3928, he presses the button (a circuit-closer) of his instrument, sending an electric current to *B*. A bell is thus rung and a needle caused to point to "Train on Line." The inclination of this needle, however, closes automatically a return current from *B* to *A*, which causes a needle to incline at *A* to give a similar indication. This constitutes the repeating signal. If the announcing signal is not received at *B*, no repeating signal can be returned to *A*. This repeating signal at *A*, which blocks the line after the departure of the train, cannot be changed by the attendant at *A*, but only by the attendant at *B*, who after the arrival of the train at *B* sets his instrument and that of *A* to indicate "Line Clear."

Instead of the needles, miniature semaphore signals similarly operated are sometimes used.

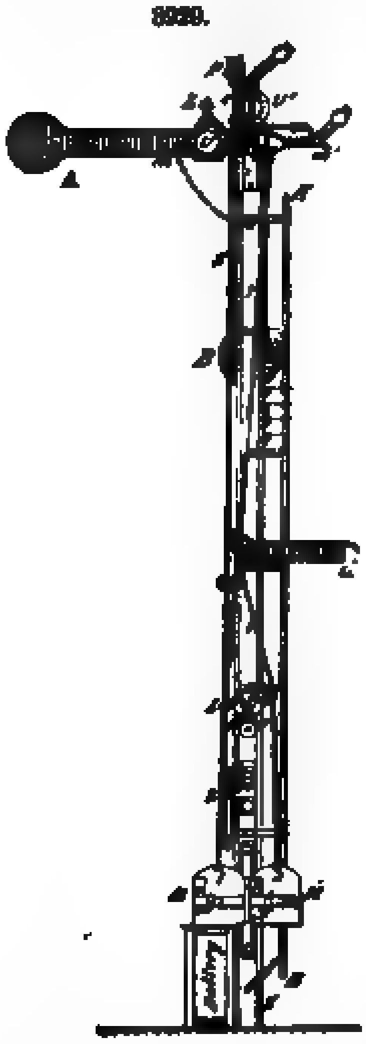
It will be noted that the above devices simply transmit instructions to attendants, without compelling execution; and hence, by mistake or carelessness, the signalman may give a wrong outdoor signal. The *electric-slot signal* prevents this by restricting the power of an attendant to give a safety signal to a train without the consent of the attendant at the other extremity of the block section. Such an apparatus, interlocking the road signals, and also the switches, with the telegraphic signals, thus combining the interlocking with the block system, was exhibited at the Paris Exposition of 1878, by Messrs. Saxby and Farmer. The three signals, "Line Clear," "Train on Line," and "Line Blocked," were used, the last meaning the acknowledgment of the receipt of the "Train on Line" signal, and being employed only as an auxiliary in the system of interlocking. The apparatus makes it compulsory that the signals shall be operated in a certain desired order. It also places certain restrictions on the action of the operator, which are by the inventors summed up as follows: 1. It makes it impossible for the signalman to telegraph "Line Clear" until the switches and outdoor signals are in the proper position. 2. It makes it impossible to move switches for shunting or giving access to a line which has been signaled as "clear" for an expected train, nor in any case can such movement of the switches be made until *after* the "Line Blocked" signal has been sent to the station on either or both sides. 3. The signal "Train on Line" must be transmitted to the station in advance before the outdoor signal for a train to enter a block section can be given, so that it is not possible for a train to enter a block section unannounced by telegraph to the station in advance. 4. The outdoor starting signal cannot be given to permit entrance into a block section without the consent and concurrent action of the signalmen at both ends of such block section. 5. The mechanism makes it compulsory that the outdoor starting signal shall be reset to danger behind every train, and that upon the entrance of a train into a block section the signalman at the station in advance shall give to the signalman at the station in the rear the proper signal of "Line Blocked" behind the coming train.

2. *Mechanism connected with Road Signals.*—To the second class noted on page 767 belong the apparatus of Siemens and Halske, and of Lartigue, Tesse, and Prudhomme, called "electro-semaphores," which are manipulated by attendants, and those of Hall and of Rousseau, which are automatic.

Electro-Semaphores.—Fig. 3929 represents a complete electro-semaphore according to the system of Lartigue, Tesse, and Prudhomme, for a double-track road, as used on the Northern Railroad of France. The road is divided into sections, at each end of which is placed an electro-semaphore, which is constructed as follows: Two large semaphore-arms, *A* and *B*, serve as signals to be observed by the trains. Two small semaphore-arms, *a* and *b* (*b*, being behind the post, is not shown in the cut), are the signals announcing to the attendant the departure of trains from the other extremities of the two neighboring sections. Two electro-magnetic instruments for the up line, *M M'*, are placed at one side of the semaphore, and two for the down line are placed at its other side. A battery situated at the foot of the semaphore supplies the electric currents. The two electro-magnetic instruments for each track are numbered 1 and 2, and are connected by telegraphic wires with the instruments of the neighboring semaphores, so that instrument No. 1 is connected with instrument No. 2 of the advanced semaphore, and instrument No. 2 communicates with instrument No. 1 of the semaphore in the rear. These instruments are identical in construction, the latter being shown in Figs. 3930 and 3931, which are side and end elevations, respectively. On a shaft *X X* are fixed two cranks, *M* and *B*, projecting on the outside at a box which encases the apparatus; one of them, *M*, is provided with a handle, to be moved by hand, and the other, *B*, is connected with the semaphore-arm by a rod. Instrument No. 1 is connected with the large, and instrument No. 2 with the small semaphore-arm. The two cranks form an angle of 90° with each other. A detent *W* opposes the rotation of the shaft to the right, acting on a ratchet which determines two positions of the shaft: one with the crank *B* vertical (when the large semaphore-arm is down), and the other at 210° from it (when the semaphore-arm is

horizontal). On the shaft X are also fastened a finger D, fixed at an angle of 150° to the crank B; a spiral cam C; and a disk O, of a non-conducting material. Two prismatic levers J and r, forming a constant angle with each other, are attached to another shaft, F—the lever J being in the plane of the cam C, and the lever r in the plane of the finger D. At the bottom of the lever r is attached an armature p of a strong magnet A, whose two branches end in soft-iron cores, surrounded with bobbins through which an electric current can be sent. The lever r is connected with a stop P, which, being in the plane of the finger D, prevents its passing the second fixed position, namely, when the large semaphore-arm is horizontal. This, however, happens only when the armature p is attracted by its magnet. When the arma-

8929.



8930. 8931.

ture is liberated from the magnet, the stop P being no longer a support to the finger D, the latter then is free to fall. The armature p is liberated from its magnet only by the action of an electric current which, passing through the bobbins, weakens the magnetic force; and this current can be sent only from the semaphore of the neighboring post. When the finger D removes its support, the shaft X is no longer locked in its fixed position, and consequently the large semaphore-arm will fall by its own weight. The semaphore-arm can be brought back to a horizontal position by the crank M being turned over an angle of 210° by hand, in which case the cam C will lift the lever J, and consequently bring the armature p again in contact with the magnet, and place the stop P under the finger D, preventing any further rotation, and locking the arm. It will be observed that the large semaphore-arm is placed in the horizontal *danger* position mechanically by the attendant, and that it is locked in this position and cannot be reset to *safety* by him, but only by the signalman at the other extremity of the section. The small semaphore-arm which is acted on by instrument No. 2 (identical with instrument No. 1) is so counterweighted as to take a horizontal position when liberated from the action of the magnet, and *vice versa*. The horizontal position of the small semaphore-arm is thus affected by the action of the attendant at the semaphore of the neighboring post, and it announces that a train has just entered on the section.

The disk O, which rotates with the shaft X, is a circuit-closer. It is made of non-conducting material, but it has on its circumference seven metallic plates. Three pairs of these are connected, and the seventh plate passes through the shaft X to the ground. The disk rotates between four triangular prisms, which come in contact with the seven metallic plates during the rotation. These prisms are connected respectively with the positive and negative poles of the battery, with the bobbins of the magnet A, and with the line-wire which leads to the neighboring semaphore-post. As the disk rotates, the electric currents are established or broken between each two of the prisms. In the different positions of the semaphore-arms electric communication is established or broken as follows: When the semaphore-arm is liberated from the action of the magnet (the large arm being down and the small arm horizontal), no communication between the prisms exists, and consequently no electric current passes. When the semaphore-arm is locked by the action of the magnet (in the reverse position of the arms), a communication is established between the line-wire and the bobbins of the magnet; the position of the arms can then be reversed by the signalman at the other extremity of the section. During the rotation of the disk, which occurs when the arm changes position, one pole of the battery is placed momentarily in communication with a line-wire, causing actions to be presently described.

There is another magnet R attached to the apparatus, which acts on a target V, on which are written the words "Free" and "Blocked." As this target is attracted or liberated by the magnet (an armature being attached to a lever which moves the target), these two words can be seen alternately through an opening made for this purpose in the casing of the apparatus; and at the same time a stroke on a bell T, by a bell-hammer t which moves with the target, gives an audible signal, announcing that a current is passing. The bobbins of the magnet R communicate with those of the magnet A in such a manner that the positive pole of one connects with the negative of the other, and *vice versa*. By this arrangement, if either negative or positive current is sent through the wire, it will strengthen the power of one and weaken that of the other magnet.

To explain now the operation of the electro-semaphores, let us consider the road divided into sec-

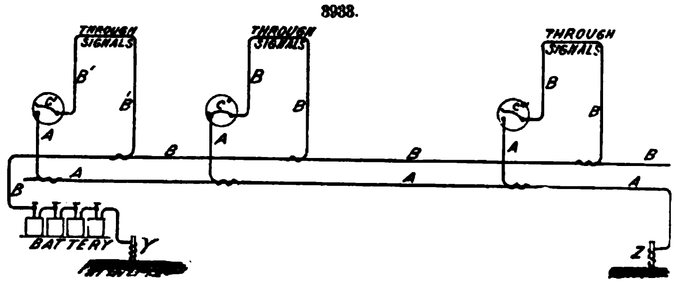
tions by the signal-posts *X*, *Y*, *Z*, Fig. 3932. A train having started from the initial post *X*, the signalman there turns the crank of instrument No. 1 (the initial post has no instrument No. 2), raising the large semaphore-arm to danger. Before the arm has reached that position, a momentary negative current is sent on the line-wire to instrument No. 2 of the semaphore at *Y*, where it liberates the small semaphore-arm from the magnet, placing it thus horizontally and announcing the departure of a train. And while the small semaphore-arm at *Y* is changing its position, a positive current is sent through the line-wire from instrument No. 2 at *Y* to instrument No. 1 at *X*, which strengthens the power of the magnet *A* and weakens that of the magnet *R*, in consequence of which the target *V* is liberated and the word "Blocked" can be read on it. This is also accompanied by a stroke on the bell *T*. The attendant at *X* has thus received an announcement that the electric signal sent by him to *Y* has been actually produced there. When the train arrives at *Y*, the attendant there manipulates his instrument No. 1, producing at *Y* and *Z* the same effects as those just described. This done, he turns the crank of instrument No. 2, setting his small semaphore-arm vertically, and thus removing the announcement of a train which he has formerly received from *X*. This action on instrument No. 2 at *Y* sends a negative current to instrument No. 1 at *X*, which neutralizes the power of the magnet *A*, liberating thus the large semaphore-arm, which falls to safety, and opens the section *X Y* for a succeeding train. Again, while the large semaphore-arm at *X* is falling to safety, a positive current is transmitted from instrument No. 1 at *X* to instrument No. 2 at *Y*, where it produces a movement of the target on which the word "Free" can be read, announcing thus to the attendant at *Y* that his signal has been produced at *X*. A stroke on the bell accompanies this.

3932.

Hall Automatic Electric Signals.—This system of signaling does not require attendants, as it is operated by the action of the moving trains. The entrance to each block section is protected by two signals, placed about 1,000 feet apart. Each signal is of the disk form, and is placed, together with an electro-magnetic apparatus, in a water-tight box which is attached to a high post, so as to be visible from a long distance. The boxes have round openings, covered with glass, through which the disks are visible when displayed. The signal which is placed immediately at the entrance of a section is called the "danger signal," and the other, placed 1,000 feet farther off, the "safety signal." But each of them when displayed indicates *danger* to the approaching train, and if hidden from view indicates *safety*. The two signals are connected by electric wires, and are so arranged that when one of them is displayed the other is hidden, and *vice versa;* the change of position of one of the signals producing a reversal of the other. The second signal is called the "safety signal," as it gives to the engine-driver a constant knowledge of the working order of the apparatus. At the entrance to a section is also placed a "track instrument," which, being acted on by a passing train, sets the signals in the *danger* position, to close this section. Another track instrument, placed about 1,600 feet distant from the first, reverses the rear signals, setting them in the *safety* position, to open the rear section for a following train. The electro-magnetic devices which move the signals are connected by wires with one pole of a battery and with the ground. The track instruments are circuit-closers, which are interposed in the wire connecting the signals with the ground. The instrument which sets the signals at danger, which for distinction may be termed No. 1, connects with the danger signal, while the other, No. 2, connects with the safety signal.

One peculiarity of the Hall system of signals is, that only one battery need be used for the whole line. This advantage is obtained by such a disposition of the wires as to equalize the electric resistance over the line. Fig. 3933 explains this. One pole of a battery is connected with a wire *B*, called the "battery wire," which extends over the whole line, and ends unconnected. Another wire *A*, called the "ground wire," also extends over the whole line. One end of this is connected with the ground at *L*, and the other end is left free. The other pole of the battery connects with the ground at *Y*. At different points of the line, branch wires *A A A* are run from the ground wire to the circuit-closers *C' C'' C'''*, which are the track instruments. The latter are further connected by wires *B B B* (which on their way pass through the signal apparatus) with the battery wire. If any of the circuit-closers are closed, an electric circuit is established. In Fig. 3933 the circuit-closer *C''* is represented as closed. The current will therefore travel from one pole of the battery, through the battery wire *B*, the branch *B*, the circuit-closer *C''*, the branch *A*, and the ground wire *A*, to the ground at *Z*, and hence through *Y* to the other pole of the battery, or *vice versa*. It is evident that whether the circuit-closer *C'* or *C'''* be closed, the length of wire passed over by the current will be the same as that of the circuit just described.

3933.



The track instrument is illustrated in Figs. 3934 and 3935, representing its vertical section and plan. In Fig. 3935, the cap *D* is removed. The lever *L* is pivoted at *A* in a bracket which is bolted to a cross-tie. One end of the lever extends to within a short distance of the track rail, being some-

what elevated above the top of the latter, so that a wheel of a passing train must depress it, and thus swing it on its pivot. Two rubber springs, R and r, serve to diminish the intensity of the shock, and to bring the lever back to its normal position. The other end of the lever L enters into a casting G, which is also bolted to the cross-tie; a sliding cover H prevents the dust from entering inside of the casting. The casting is divided into two chambers. The upper chamber K is an air-cylinder, in which a piston P is fitted. The piston is provided with a rod p, the lower end of which stops

3934.

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by connecting the spaces above and below the piston by air-passages, q, t, o, in which a small valve s opens communication freely when the air is flowing from above the piston to below it, but leaves only a small opening when the direction of the air-current is reversed.

The signal apparatus is shown in Figs. 3936 and 3937, representing its front and side elevations. It consists of a disk A attached to a lever $B\,B$, fastened on a shaft $X\,X$, with which it swings. The disk as shown at A is in a pendent position, and as shown in half, in dotted line, is in a raised position.

3935.

It is brought from the first into the second position by the action of an electro-magnet, and is held so by means of a mechanical support. It is brought back into the depressed position by its own gravitation, the mechanical support being removed by the action of another electro-magnet. This is accomplished by the following arrangement: On the shaft $X\,X$ is fastened a wheel a, to the circumference of which is fixed one end of a chain b, its other end being attached to a rocking lever K. The lever K is connected by a rod R with another rocking lever F, pivoted at z, at the other end of which is attached an armature h of an electro-magnet M. In the position shown in the drawing, the armature h is liberated from its magnet; but when the electro-magnet M becomes excited by an electric current, it will attract the armature, swinging the lever F into the position $z\,g'$ (shown in dotted line), and thus raising the end f of the rocking lever K to the position f'. The chain b, being thus pulled, will swing the shaft X, and with it also the disk A, into the raised position. As soon as the lever F has been raised, another lever L, which is pivoted on the axis o and counterweighted by a weight w, will swing from the position $o\,n$ into the position $o\,n'$ (shown in dotted line), and a stop i of the lever F will then rest on the top of the lever L, thus supporting the disk in its raised position. The lever L carries an armature t of a second electro-magnet N, which when energized by the action of an electric current will attract the armature and thus bring the lever L back into its former position; by which action, the support of the lever F being removed, the lever will fall down, together with the lever K, to the first position; the chain d will consequently be slackened, and the disk will be allowed also to fall by its gravity The electro-magnet M is excited by the electric current established by track instrument No. 1, which closes a section, and electro-magnet N is excited by track instrument No. 2, which opens a section

The mechanical arrangement of the danger and safety signals is similar, the only difference being that the first is displayed when in its raised position, and the second is displayed when in its pendent position, so that both are either raised or lowered at the same time.

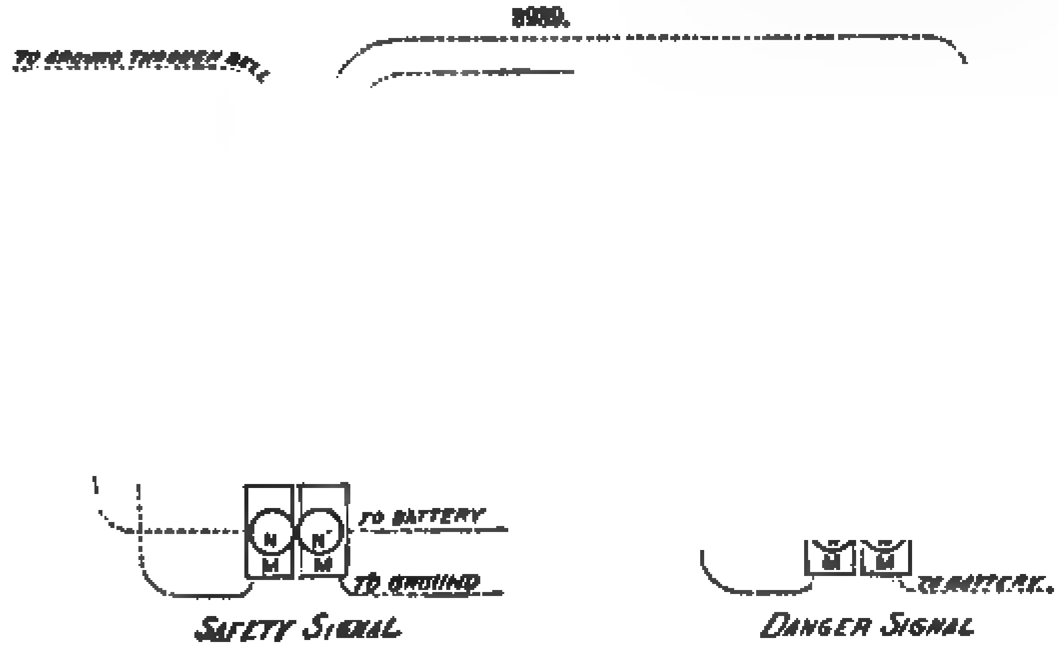
All wires for electric transmission are connected to metallic plates which are marked in the drawing from 1 to 8, and which are attached to an insulated plate, across which the shaft X passes. This portion of the apparatus is called the "circuit-closer and cut-out," and is shown also separately in Fig. 3938, with some parts detached. On this insulating plate is placed a lever $H\,H$, which can be brought

in contact with plates 1 and 2, or 3 and 4, and thus close or break a circuit between them. This lever is provided with two legs $v\ v'$, projecting downward. With the shaft X moves also a finger P, which carries at its end an insulated stud m. The stud swinging with the shaft X touches one or the other of the two legs $v\ v'$, and swings the lever H, either in the position shown in Fig. 3936, or that shown in Fig. 3938. Plates 6 and 8 have attached to them spring circuit-closers, the other ends of which can be brought momentarily in contact with plates 5 and 7, respectively, by the action of the same stud m, which, as the shaft X swings one way or another, passes its fixed position by the action of momentum of the swinging parts which are attached to it.

3938.

The connections of the wires and the transmission of currents can now be explained from the diagram Fig. 3939. The safety and danger signals are shown raised in the position of *danger*. The section is then occupied by a train, and consequently the signals will remain in this position until the train has entered the succeeding section and passes over track instrument No. 2, closing a circuit. As this instrument connects with the safety signal by means of its connector 2, a circuit will be closed which runs from the ground through track instrument No. 2, the safety signal, its connector 2, circuit-closer H, connector 1, electro-magnet $N\ N$, and thence through the battery to the ground again; or *vice versa*. The connection of wires is indicated by dotted lines in the diagram.

3939.



As the electro-magnet $N\ N$ becomes excited, it produces a fall of the disk of the safety signal, which is thus displayed as seen in dotted line. At the same time the circuit-closer H swings from the position indicated by a full line to the position H', shown in dotted line, and thus breaks the described circuit. The action of the electro-magnet is thus momentary, and as soon as the stroke of one of the wheels of a train has produced the current, all subsequent strokes of the remaining wheels are without effect. At the same time that the above is accomplished, the spring circuit-closer T of the safety signal closes another circuit and establishes a cur-

rent which runs from the ground through connector 6, circuit-closer *T*, connector 5, all of the safety signal, then through the danger signal by its connector 2, circuit-closer *H*, connector 1, to the electro-magnet *N N*, and thence through the battery to the ground again; or *vice versa*. This causes the disk of the danger signal to fall and be hidden. The circuit-closer *H* of the danger signal will now switch off into the position indicated by the dotted line. The signals are thus set to *safety*, and if a train enters on the section it strikes track instrument No. 1, which connects with connector 8 of the danger signal, and the currents—which the reader can now easily make out for himself—will, acting on the electro-magnets *M M* of the danger and safety signals, raise both of the disks to the *danger* position. It will be observed that the position of the safety signal shows to the trainmen who enter a section whether the danger signal has been displayed behind the train; in other words, whether the apparatus is in a working condition. Should the safety signal be displayed after the train passed a hidden danger signal, a derangement of the apparatus would be discovered and reported at the nearest station. The safety signal is thus only a controlling apparatus. If the signals are placed at the entrance to a depot, the safety signal has another spring circuit-closer *J'*, which when the disk rises is closed, thus sending a current through an electric bell placed at the station, announcing the approach of a train.

In connection with the Hall signals, track instruments are used to strike bells on road-crossings, warning flagmen that a train is coming. A special "switch instrument" is also used, which interlocks the signals with switches in such manner that, whenever a switch is set wrong to the main line, the signals are set automatically at *danger*, and when the switch is placed back for the main line, the signals are set at *safety*. In a similar manner the draw of a bridge is interlocked with the signals.

Rousseau's Automatic Signal consists of a disk (Fig. 3940) which revolves on a vertical shaft moved by clock-work. This vertical shaft has four horizontal arms, which, coming in contact with a stop *E*, prevent the rotation of the disk. The stop *E* carries an armature of an electro-magnet *D*, which, when momentarily attracted, moves the stop and releases the arm. The disk will then revolve, but only a quarter of a revolution, as the next arm will be engaged by the "stop." In this way the disk will take alternately a parallel or perpendicular position to the track. A track instrument, shown in Fig. 3941, which is a circuit-closer, is placed under a rail, and during the passage of a train closes a circuit, momentarily exciting the electro-magnet of the signal apparatus. As soon as the change of position of the disk has been produced by the action of the track instrument, a circuit-closer attached to the signal apparatus breaks the current; but at the same time a second circuit-closer is closed by the rotation of the shaft, setting the signal apparatus in electric communication with another track instrument, which is placed at the other end of a railroad section protected by this signal. This, being actuated by a train, will place the signal back to its former position. Thus the signal cannot be moved to danger and back to safety by the same track instrument, but by the alternate action of the two. The automatic action can be dispensed with if desired, by substituting for the track instrument an apparatus worked only by hand.

3940.

3941.

Works for Reference.—"On the Fixed Signals of Railways," Rapier, London, 1874; "Treatise upon Railway Signals and Accidents," Dawney, London, 1874; "Railway Appliances," Barry, London, 1876; "Note sur le Block-System et sur quelques Appareils," etc., Sartiaux, Paris, 1877; "Note sur l'Emploi des Electro-Sémaphores de MM. Lartigue, Tesse et Prudhomme, pour la Réalisation du Block-System," Clérault, Paris, 1877. See also the following papers in the *Railroad Gazette*: "Interlocking Switches and Signals," vii., 424–427 (Toucey-Buchanan System), 448–455 (Saxby and Farmer System), 477–479 (Brierly System); "The Burr Pneumatic Interlocking Apparatus," ix., 251; "The Rousseau Electric Signal System," ix., 230 and 241; "Saxby and Farmer's Union of the Block and Interlocking Systems," x., 341, 342; "Semaphore Signals," x., 477–479; "Chambers's Pneumatic Signals," xi., 55; "Electro-Semaphores of Lartigue, Tesse, and Prudhomme," xi., 93, 95, 108, 109; "The Hall Automatic Electric Railroad Signals," xi., 563–590. T. F. K.

SILK-SPINNING MACHINERY. The machinery used in the fabrication of silk is very simple, as compared with that required for cotton or wool. The long and ingenious series of processes by which an even and continuous thread is produced from a tangled collection of short fibres are here unnecessary, the only end to be accomplished being that of uniting a sufficient number of the

delicate fibres spun by the silk-worm to form such a thread as is required for the purpose for which it is intended; to clean the raw silk from the gum which it holds in its natural state; and to free it from knots and imperfections.

The thread as produced by the worm is composed of two filaments, which are spun simultaneously and cemented together. When wound into the cocoon the coils mutually cohere to each other, but readily separate upon being immersed in warm water, so that the entire thread may be reeled off. As many of these filaments as may be desired are reeled off together, and become cemented so as to form a thread. In this state it is the *raw silk* of commerce, and is exported to the United States from China, Japan, and Italy, made up into hanks or bundles. The length of each filament is usually about 800 yards. Of average cocoons, 250 weigh about a pound, and 12 lbs. of cocoons yield a pound of silk.

Washing and Winding.—The raw silk is first inclosed in a light cotton bag and soaked in warm water at 110° F. for a few hours. The water is then removed, and the silk left in a softened state by the hydro-extractor. The silk is then placed upon reels and thence wound upon spools. The reels are six-sided, and are technically called *swifts*. They are adjustable to suit the sizes of the hanks, and are balanced so that they will not break the threads by irregular motion. By means of weights enough friction is produced upon their axes to keep the threads stretched. The bobbins have each an independent motion, and any one can be taken off and replaced without interfering with the others. An eye through which the thread passes to the bobbin has a traverse motion by which the thread is wound obliquely and lateral adhesion is prevented.

Cleaning—or, as it is sometimes termed, "clearing"—is performed by fixing the bobbins horizontally on plain spindles and passing the thread between two adjustable pieces of metal. Should a knot or other unevenness chance to be on the thread, these metal blades prevent its passing through, one of the plates becomes depressed, and the bobbin is lifted off the friction-roller which gives it motion. The stoppage being perceived by the attendant, the defect is removed and the work proceeds.

Twisting or Throwing.—Silken thread merely wound and cleaned is called *dumb singles*. If twisted to add to its strength and firmness, it is termed *thrown singles*, or simply *singles*. Two or more singles twisted together—that is, single-twisted loosely—form *tram*, which is used as the weft in weaving. When two singles are twisted together in an opposite direction to that in which the singles themselves are twisted—that is, so that the resulting thread is double-twisted—the process is called *throwing*, and the product *thrown silk* or *organzine*. This is generally used as the warp in weaving. For silk gauze dumb singles are used; for ribbons and common silk, thrown singles; for the best silk, tram and organzine. *Doubling* is the process of bringing two or more twisted threads into one and winding them preparatory to spinning.

The Silk-Spinning Frame constructed by the Danforth Locomotive Works of Paterson, N. J., is represented in Fig. 3942. On this the spools of doubled thread are placed, and a certain number of turns per inch is given to the filaments, this twist being regulated by the speed of the delivery rolls,

which are in single pairs, and not compound as in cotton-spinning, no stretch being given or required. The threads are again doubled or twisted by a second operation.

From the spinning frame the silk is transferred to the reel-mill, Fig. 3943, where it is again wound into skeins, and is ready for the dyer.

SPINNING WASTE SILK.—Waste silk is of two kinds—that produced directly from the cocoons, and that which accumulates in the course of manufacture. It is first submitted in short lengths or "stricks" to the processes of softening, washing, opening, filling, and dressing, when it is ready for the first machine of the series, which is the *spreader*, and in which the silk passes over a porcupine roller and through a series of combs, and is delivered upon a drum. From the spreading machine the silk is taken to the *sett* or *slivering machine*, which is constructed similarly to the spreader, with the exception that the silk is delivered into a can instead of being wound round a roller. From the slivering machine the silk is taken to the *drawing machine*, which has fine gills placed closely together. The sliver then passes to the *roving frame*, where it is still further reduced by being passed through a very fine screw-gill. The rove is now ready for spinning, and is removed to the spinning frame, which is similar in construction to those used in dry flax- and worsted-spinning. Here the rove is greatly reduced in size, and is twisted and wound upon a bobbin, to be afterward doubled in similar manner to cotton, flax, and other yarns. Finally, the silk thread is taken to the reeling machine, where it is made into hanks. A very full illustrated account of the machines devised by Messrs. Greenwood & Batley of Leeds, England, and by which the above-described process is accomplished, appears in *Engineering*, xviii., 6 *et seq.*

SINGEING MACHINE. See CLOTH-FINISHING MACHINERY.

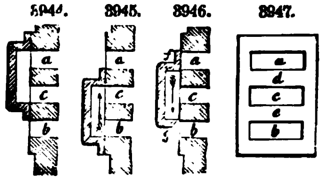
SIZING MACHINE. See HAT-MAKING MACHINERY.

SLICKING MACHINE. See LEATHER-WORKING MACHINERY.

SLIDE-REST. See LATHE-TOOLS, TURNING (SLIDE-REST).

SLIDE-VALVE. The valve which controls the admission or exit of steam from the cylinder of an engine. The general nature of this arrangement is illustrated in Figs. 3944 to 3947, for the case in which the valve is just long enough to cover the ports, the figures showing the slide in its central and two extreme positions. It occupies the mid-position, Fig. 3946, when the piston is at either extremity of its stroke; the extreme position, Fig. 3945, when the piston is at half-stroke in its descent; and that shown in Fig. 3944, when the piston is at half-stroke in its ascent.

3944. 3945. 3946. 3947.



When a slide has no lap, the width of its facing, at *f* and *g*, Fig. 3946, equals that of the steam-ports, the lap being any additional width whereby those ports are overlapped.

That the waste steam may have unobstructed egress, the exhaust-port *c* must be made of no less width than the steam-ports; and, for the same reason, the bars *d* and *e* should correspond with the slide-face at *f* and *g*. The three ports, together with the bars between and beyond them, are therefore drawn of equal width; the total length of the slide being equal to the distance between the steam sides of the steam-ports. The distance through which the slide moves, in passing from one extreme position to the other, is called its *travel*, which, in this case, equals *twice the width of port.*

When the motion of a slide is produced by means of an eccentric, keyed to the crank-shaft and revolving with it, the relative positions of the piston and slide depend upon the relative positions of the crank and eccentric.

In proportioning a slide-valve, it is commonly designed so that the *admission*, *cut-off*, *release*, and *compression* of the steam shall occur at certain definite points of the stroke. The literature relating to the slide-valve is quite extensive. Among the most recent and approved works upon the subject are: "Link and Valve Motions," by W. S. Auchincloss; "A Practical Treatise on the Movement of Slide-Valves," by C. W. MacCord; and "Treatise on Valve Gears," by Gustav Zeuner. The methods explained in the present article are principally derived from the last-named work. An explanation of the arrangement of link-motion is contained in the article LOCOMOTIVE, DESCRIPTION OF PARTS OF THE.

The travel of a slide-valve which is just long enough to cover the ports is equal to twice the width of port-opening. If the valve is lengthened on the steam side, this addition is called *steam-lap*, and an addition to the exhaust side is called *exhaust-lap*. The effect of steam-lap is to cut off the steam at an earlier part of the stroke, and exhaust-lap causes the exhaust to open later and close earlier than it otherwise would. The amount of opening for the admission of steam at the beginning of the stroke is called *steam-lead*, and the opening for release at the end of the stroke is *exhaust-lead*. If a valve has neither lap nor lead, the eccentric is secured to the shaft in such a position that a line joining its centre with the centre of the shaft is perpendicular to a line connecting the centre of the shaft and the centre of the crank-pin. If the valve has lap or lead, the eccentric must be moved ahead so that the line joining its centre and the centre of the shaft makes an angle, called the *angular advance*, with its former position. By marking the central line on the eccentric, it can be readily adjusted when the angular advance is determined. The area of port-opening for any given case should be such that the velocity of the steam in passing through it will not exceed 100 ft. per second. The accompanying table can be used in determining the area:

Speed of piston, in ft. per minute..	100	200	300	400	500	600	700	800	900	1000	1100	1200
Port area = piston area ×	.02	.04	.06	.07	.09	.1	.12	.14	.15	.17	.19	.2

Thus, for an engine with a cylinder 40 in. in diameter and 4 ft. stroke, making 50 revolutions a minute, the port area should not be less than 1256.6 × 0.07 = 88 sq. in.; and if the length of the port is equal to the diameter of the cylinder, its width is 88 ÷ .40 = 2.2 in.

The width of opening given by the motion of the valve is frequently greater than the width of

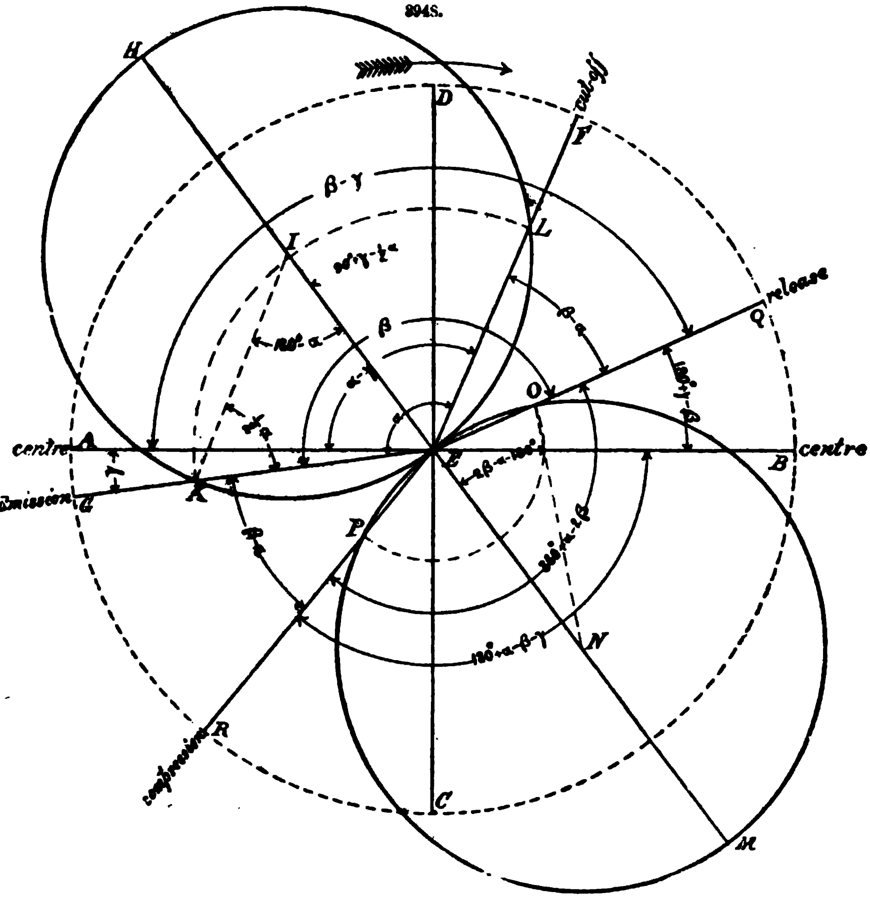
port, so that the bridge between steam- and exhaust-ports should be wide enough to prevent a leak into exhaust due to over-travel. The following rules are given by Auchincloss:

Minimum width of bridge = width of opening + $\frac{1}{4}$ in. − width of steam-port.

$$\text{Width of exhaust-port} = \text{width of steam-port} + \frac{\text{travel of valve}}{2} - \text{width of bridge.}$$

The principal questions relating to travel and lap of valve can be readily solved by the aid of the accompanying diagram and tables. In Fig. 3948, $A\,B$ represents the stroke of the piston. $D\,C$ is perpendicular to $A\,B$. $G\,E$ is the central line of the crank at the instant of *admission*; $F\,E$, at *cut-off*; $Q\,E$, at *release*; and $R\,E$, at commencement of *cushion*. $H\,E$ bisects the angle $G\,E\,F$, and $E\,M$ is a continuation of $H\,E$. I and N are the centres of two circles of which $H\,E$ and $E\,M$ are the diameters. Then, $\frac{E\,L}{H\,E} = \frac{E\,K}{H\,E} = \frac{\text{steam-lap}}{\text{half travel of valve}}$; $\frac{E\,O}{E\,M} = \frac{E\,P}{E\,M} = \frac{\text{exhaust-lap}}{\text{half travel of valve}}$; and $H\,E\,D$ = angular advance of eccentric. By Table I. the travel of the valve and the steam-lap can be found when the angle $G\,E\,F = \alpha$ is known; and Table II. gives this angle for any desired point of cut-off, and for various lengths of connecting-rod. Table I. also gives the exhaust-lap

3948.



when the angle $G\,E\,Q = \beta$ is known. The angular advance can be found from Fig. 3948 if the lead-angle $G\,E\,A = \gamma$ is given; and any of the other positions can be found from the figure, as indicated. In using Table I., the angle α is always to be taken for finding the travel of the valve, and the angle β is to be used only in calculating the exhaust-lap. Where a valve has no exhaust-lap, the angle $\beta = \alpha$ + angular advance.

To illustrate the preceding principles, suppose that the width of port, as calculated in the former example, is 2.2 in.; that the width of opening is to be 2.5 in.; that the connecting-rod is $2\frac{1}{2}$ times the stroke; that the cut-off is to take place at three-quarters of the stroke, the release at $\frac{95}{100}$; and that the lead-angle is to be 10°. By Table II., $\alpha = 114.6° + 10° = 124.6°$; hence by Table I. the travel of valve is $2.5 \times 3.738 = 9.45$ in., and the steam-lap is $9.45 \times 0.2324 = 2.2$ in. Since $\beta = 151.3° + 10° = 161.3°$, the exhaust-lap is $9.45 \times 0.0811 = 0.77$ in. By Fig. 3948, the angular advance of the eccentric is $90° + 10° - 62.3° = 37.7°$, and the crank-angle at commencement of

cushion is 180° + 124.6° − 161.3° − 10° = 133.3°, corresponding, by Table II., to a piston position of about 0.81 of the stroke.

The positions determined above are for the forward stroke of the piston. On the return stroke, the cut-off will take place at the same crank-angle, 114.6°; but to correspond to the same piston position, as will be seen by Table II., it should take place at a crank-angle of 124.6°. By a slight adjustment of the angular advance and the length of the eccentric rod, the cut-off can be equalized. This adjustment is fully explained in Auchincloss's work, referred to above. The width of bridge should be at least 2.5 + 0.25 — 2.2 = 0.55 in.; and the width of exhaust-port, $2.2 + \frac{4.1}{2} - 0.55 = 3.7$ in.

The above method of proportioning valves does not take into account the effect of the angularity of the eccentric-rod. This effect is generally inappreciable, owing to the length of the connection. The reader will find this point fully discussed in Zeuner's work, from which the method is derived.

TABLE I.—*Lap and Travel of Valve.*

ANGLE Between Positions of Crank at Instants of Admission and Cut-off, or Release and Cushion.	Ratio of Lap to Travel of Valve.	Ratio of Travel of Valve to Width of Port Opening.	ANGLE Between Positions of Crank at Instants of Admission and Cut-off, or Release and Cushion.	Ratio of Lap to Travel of Valve.	Ratio of Travel of Valve to Width of Port Opening.	ANGLE Between Positions of Crank at Instants of Admission and Cut-off, or Release and Cushion.	Ratio of Lap to Travel of Valve.	Ratio of Travel of Valve to Width of Port Opening.
Degrees.			Degrees.			Degrees.		
31	.4818	55.01	81	.3802	8.347	131	.2074	3.417
32	.4806	51.63	82	.3774	8.153	132	.2034	3.371
33	.4794	48.57	83	.3745	7.967	133	.1994	3.326
34	.4782	45.77	84	.3716	7.786	134	.1954	3.283
35	.4769	43.22	85	.3686	7.613	135	.1913	3.240
36	.4755	40.87	86	.3657	7.445	136	.1873	3.198
37	.4742	38.70	87	.3627	7.283	137	.1833	3.157
38	.4728	36.71	88	.3597	7.126	138	.1792	3.117
39	.4713	34.87	89	.3566	6.975	139	.1751	3.078
40	.4699	33.17	90	.3536	6.828	140	.1710	3.040
41	.4683	31.58	91	.3505	6.687	141	.1669	3.002
42	.4668	30.11	92	.3473	6.550	142	.1628	2.966
43	.4653	28.74	93	.3442	6.418	143	.1587	2.930
44	.4636	27.47	94	.3410	6.289	144	.1545	2.894
45	.4619	26.27	95	.3378	6.165	145	.1504	2.860
46	.4603	25.16	96	.3346	6.045	146	.1462	2.826
47	.4585	24.11	97	.3313	5.928	147	.1420	2.793
48	.4568	23.13	98	.3280	5.815	148	.1378	2.761
49	.4550	22.21	99	.3247	5.705	149	.1336	2.729
50	.4532	21.34	100	.3214	5.599	150	.1294	2.698
51	.4513	20.53	101	.3180	5.496	151	.1252	2.668
52	.4494	19.76	102	.3147	5.396	152	.1210	2.638
53	.4475	19.04	103	.3113	5.298	153	.1167	2.609
54	.4455	18.35	104	.3078	5.204	154	.1125	2.581
55	.4435	17.70	105	.3044	5.112	155	.1082	2.553
56	.4415	17.09	106	.3009	5.023	156	.1040	2.525
57	.4394	16.50	107	.2974	4.936	157	.0997	2.498
58	.4373	15.95	108	.2939	4.852	158	.0954	2.472
59	.4352	15.43	109	.2904	4.770	159	.0911	2.446
60	.4330	14.93	110	.2868	4.690	160	.0868	2.420
61	.4308	14.45	111	.2832	4.613	161	.0825	2.395
62	.4286	14.00	112	.2796	4.537	162	.0782	2.371
63	.4263	13.57	113	.2760	4.464	163	.0739	2.347
64	.4240	13.16	114	.2723	4.392	164	.0696	2.323
65	.4217	12.77	115	.2687	4.322	165	.0653	2.300
66	.4193	12.40	116	.2650	4.255	166	.0609	2.278
67	.4169	12.04	117	.2613	4.189	167	.0566	2.255
68	.4145	11.70	118	.2575	4.124	168	.0523	2.234
69	.4121	11.37	119	.2538	4.061	169	.0479	2.212
70	.4096	11.06	120	.2500	4.000	170	.0436	2.191
71	.4071	10.76	121	.2462	3.940	171	.0392	2.170
72	.4045	10.47	122	.2424	3.882	172	.0349	2.150
73	.4019	10.20	123	.2386	3.825	173	.0305	2.130
74	.3993	9.933	124	.2347	3.770	174	.0262	2.111
75	.3967	9.679	125	.2309	3.716	175	.0218	2.091
76	.3940	9.435	126	.2270	3.663	176	.0174	2.072
77	.3913	9.201	127	.2231	3.611	177	.0131	2.054
78	.3886	8.974	128	.2192	3.561	178	.0087	2.036
79	.3858	8.757	129	.2153	3.512	179	.0044	2.018
80	.3830	8.549	130	.2113	3.464	180	.0000	2.000

However carefully the valve is proportioned and the adjustment of the eccentric effected, the engineer who desires to be certain that the valve-motion of his engine is properly arranged will make the final test and adjustment with the aid of the steam-engine indicator.

The simple slide-valve is not ordinarily employed when the cut-off is to take place at an earlier point than two-thirds of the stroke, on account of the effect produced upon the exhaust. This can be illustrated by an example. Suppose, in Fig. 3948, that $\gamma = 5°$, $\alpha = 55°$, and $\beta = 180°$; then the

TABLE II.—*Crank-Angles for Connecting-Rods of Different Lengths.*

FRACTION OF STROKE FROM COMMENCEMENT.	RATIO OF LENGTH OF CONNECTING-ROD TO LENGTH OF STROKE. Crank-Angle, in Degrees. 2		2¼		2½		2¾		3		3¼		3½	
	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.
.01	10.8	13.2	10.4	13	10.5	12.8	10.6	12.7	10.6	12.6	10.7	12.5	10.7	12.4
.02	14.6	18.7	14.7	18.4	14.9	18.1	15	17.9	15.1	17.8	15.1	17.7	15.2	17.5
.03	17.9	22.9	18.1	22.5	18.2	22.2	18.4	22	18.5	21.8	18.6	21.6	18.7	21.5
.04	20.7	26.5	20.9	26	21.1	25.7	21.3	25.4	21.4	25.2	21.5	25	21.6	24.9
.05	23.2	29.6	23.4	29.1	23.6	28.7	23.8	28.4	24	28.2	24.1	28	24.2	27.8
.10	33.1	41.9	33.5	41.3	33.9	40.8	34	40.4	34.3	40.1	34.4	39.8	34.6	39.6
.15	41	51.5	41.5	50.7	41.9	50.2	42.2	49.7	42.4	49.3	42.7	49	42.9	48.7
.20	48	59.6	48.5	58.8	48.9	58.2	49.3	57.7	49.6	57.3	49.8	56.9	50.1	56.6
.25	54.3	66.9	54.9	66	55.4	65.4	55.8	64.8	56.1	64.4	56.4	64.1	56.6	63.7
.30	60.3	73.5	60.9	72.7	61.5	72	61.9	71.5	62.2	71	62.6	70.7	62.8	70.3
.35	66.1	79.8	66.7	79	67.3	78.3	67.8	77.7	68.1	77.3	68.5	76.9	68.8	76.6
.40	71.7	85.8	72.4	84.9	73	84.3	73.5	83.7	73.9	83.3	74.2	82.9	74.5	82.6
.45	77.2	91.5	78	90.7	78.6	90.1	79.1	89.5	79.6	89.1	79.9	88.7	80.2	88.4
.50	82.8	97.2	83.6	96.4	84.3	95.7	84.8	95.2	85.2	94.8	85.6	94.4	85.9	94.1
.55	88.5	102.3	89.3	102	89.9	101.4	90.5	100.9	90.9	100.4	91.3	100.1	91.6	99.8
.60	94.2	108.3	95.1	107.6	95.7	107	96.3	106.5	96.7	106.1	97.1	105.8	97.4	105.5
.65	100.2	113.9	101.1	113.3	101.7	112.7	102.3	112.2	102.7	111.9	103.1	111.5	103.4	111.2
.70	106.5	119.7	107.3	119.1	108	118.5	108.5	118.1	109	117.8	109.3	117.4	109.7	117.2
.75	113.1	125.7	114	125.1	114.6	124.6	115.2	124.2	115.6	123.9	115.9	123.6	116.3	123.4
.80	120.4	132	121.2	131.5	121.8	131.1	122.3	130.7	122.7	130.4	123.1	130.2	123.4	129.9
.85	128.5	139	129.3	138.5	129.8	138.1	130.3	137.8	130.7	137.6	131	137.3	131.3	137.1
.90	138.1	146.9	138.7	146.5	139.2	146.2	139.6	146	139.9	145.7	140.2	145.6	140.4	145.4
.95	150.4	156.8	150.9	156.6	151.3	156.4	151.6	156.2	151.8	156	152	155.9	152.2	155.8
.96	153.5	159.3	154	159.1	154.3	158.9	154.6	158.7	154.8	158.6	155	158.5	155.1	158.4
.97	157.1	162.1	157.5	161.9	157.8	161.8	158	161.6	158.2	161.5	158.4	161.4	158.5	161.3
.98	161.3	165.4	161.6	165.3	161.9	165.1	162.1	165	162.2	164.9	162.3	164.9	162.5	164.8
.99	166.8	169.7	167	169.6	167.2	169.5	167.3	169.4	167.4	169.4	167.5	169.3	167.6	169.3
1.00	180	180	180	180	180	180	180	180	180	180	180	180	180	180

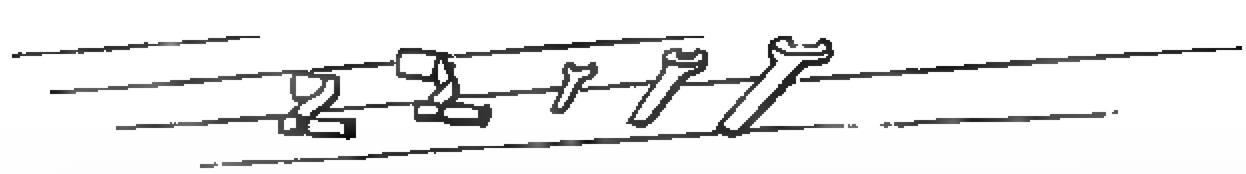
FRACTION OF STROKE FROM COMMENCEMENT.	RATIO OF LENGTH OF CONNECTING-ROD TO LENGTH OF STROKE. Crank-Angle, in Degrees. 3¾		4		4¼		4½		4¾		5		Infinite.	
	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.	Forward Stroke.	Return Stroke.
.01	10.8	12.3	10.8	12.3	10.9	12.2	10.9	12.2	10.9	12.1	10.9	12.1	11.5	Crank-angles on return stroke are the same as those for corresponding piston positions for forward stroke.
.02	15.3	17.4	15.3	17.4	15.4	17.3	15.4	17.2	15.5	17.2	15.5	17.1	16.3	
.03	18.8	21.4	18.8	21.3	18.9	21.2	18.9	21.1	19	21.1	19	21	19.9	
.04	21.7	24.7	21.8	24.6	21.9	24.5	21.9	24.4	22	24.3	22	24.3	23.1	
.05	24.3	27.7	24.4	27.5	24.5	27.4	24.6	27.3	24.6	27.3	24.7	27.2	25.8	
.10	34.7	39.4	34.9	39.2	35	39	35.1	38.9	35.2	38.8	35.2	38.7	36.9	
.15	43	48.5	43.2	48.3	43.3	48.1	43.4	48	43.5	47.9	43.6	47.7	45.6	
.20	50.2	56.4	50.4	56.2	50.6	56	50.7	55.8	50.8	55.7	50.9	55.5	53.1	
.25	56.8	63.5	57	63.3	57.2	63.1	57.4	62.9	57.5	62.7	57.6	62.6	60	
.30	63.1	70.1	63.3	69.8	63.4	69.6	63.6	69.4	63.7	69.3	63.9	69.1	66.4	
.35	69	76.3	69.2	70.1	69.4	75.8	69.6	75.7	69.7	75.5	69.9	75.3	72.5	
.40	74.8	82.3	75	82	75.2	81.8	75.4	81.6	75.6	81.5	75.7	81.3	78.5	
.45	80.5	88.1	80.7	87.9	80.9	87.6	81.1	87.5	81.3	87.3	81.4	87.1	84.3	
.50	86.2	93.8	86.4	93.6	86.6	93.4	86.8	93.2	87	93	87.1	92.9	90	
.55	91.9	99.5	92.1	99.3	92.4	99.1	92.5	98.9	92.7	98.7	92.9	98.6	95.7	
.60	97.7	105.2	98	105	98.2	104.8	98.4	104.6	98.5	104.4	98.7	104.3	101.5	
.65	103.7	111	103.9	110.8	104.2	110.6	104.3	110.4	104.5	110.3	104.7	110.1	107.5	
.70	109.9	116.9	110.2	116.7	110.4	116.6	110.6	116.4	110.7	116.3	110.9	116.1	113.6	
.75	116.5	123.2	116.7	123	116.9	122.8	117.1	122.6	117.3	122.5	117.4	122.4	120	
.80	123.6	129.8	123.8	129.6	124	129.4	124.2	129.3	124.3	129.2	124.5	129.1	126.9	
.85	131.5	137	131.7	136.8	131.9	136.7	132	136.6	132.1	136.5	132.3	136.4	134.4	
.90	140.6	145.3	140.8	145.1	141	145	141.1	144.9	141.2	144.8	141.3	144.8	143.1	
.95	152.3	155.7	152.5	155.6	152.6	155.5	152.7	155.4	152.7	155.4	152.8	155.3	154.3	
.96	155.3	158.3	155.4	158.2	155.5	158.1	155.6	158.1	155.7	158	155.7	158	156.9	
.97	158.6	161.2	158.7	161.2	158.8	161.1	158.8	161.1	158.9	161	159	161	160.1	
.98	162.6	164.7	162.6	164.7	162.7	164.6	162.8	164.6	162.8	164.5	162.9	164.5	163.7	
.99	167.7	169.2	167.7	169.2	167.8	169.1	167.8	169.1	167.9	169.1	167.9	169.1	168.5	
1.00	180	180	180	180	180	180	180	180	180	180	180	180	180	

crank-angle at commencement of cushion will be $180° + 55° - 180° - 5° = 50°$; or the cushion will be excessive, and it can only be reduced by decreasing β, or increasing the exhaust-lead, which is equally objectionable if carried very far. In practice, where an early cut-off is required, separate steam- and exhaust-valves are employed, or the cut-off is effected by a second valve, actuated by an independent eccentric, sliding on the back of the main valve, this second eccentric having motion coincident with that of the piston. R. H. B.

SLOTTING MACHINES. The slotting machine is a variety of planing machine, and is used for cutting slots or keyways in metal. Slotting machines with vertical cutting movement, says Mr. J. Richards in "Workshop Manipulation," differ from planing machines in several respects. In slotting, the tools are in most cases held rigidly, and do not swing from a pivot as in planing machines. The tools are thus held for two reasons: because the force of gravity cannot be employed to hold them in position at starting, and because the thrust or strain of cutting falls parallel and not transversely to the tools as in planing. Another difference between slotting and planing is, that the cutting movement is performed by the tools and not by the motion of the material. The cutting strains are also different, falling at right angles to the face of the table, in the same direction as the force of gravity, and not parallel to the table as in planing and shaping machines. The feed-motion in slotting machines, because of the tools being held rigidly, has to operate differently from that of planing machines. The cross-feed of a planing machine may act during the return stroke, but in

3949.

F



slotting machines the feed-movement should take place at the end of the up stroke, or after the tools are clear of the material. So much of the stroke as is made during the feeding action is therefore lost; and because of this, mechanism for operating the feed usually has a quick abrupt action, so as to save useless movement of the cutter-bar.

In Figs. 3949 to 3954 is represented an improved slotting and paring machine constructed by W. B. Bement & Son of Philadelphia, Pa.

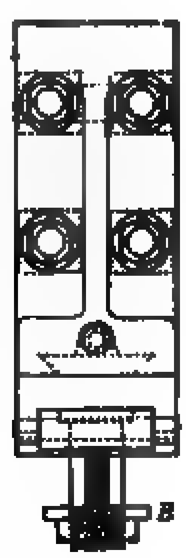
The cutting-bar *C*, Fig. 3949, receives motion from the crank *D* through a connecting-rod, the stroke being adjustable by the screw *O*. The pin to which the upper end of the connecting-rod is attached is enlarged within the cutting-bar, and tapped to receive a vertical screw which is actuated by the oblique shaft and bevel-gears *F*, raising or lowering the cutting-bar in relation to the crank-shaft. The

parts thus adjusted are secured in place by tightening the nut *E*. The inner end of the same pin is extended to receive a piece to which is jointed the end of the counterbalance lever *B*. This lever has its fulcrum in the inverted pendulum *J*, which vibrates on a pin at *M* inserted in the frame. The crank *D* has a long cylindrical hub, bored to receive the steel crank-shaft, and externally fitted into a suitable bearing in the frame, constituting in fact the crank-journal. This arrangement gives ample length for the suitable attachment of the crank to its shaft, with an extremely short distance between bearing and crank-pin. It also shortens that projecting part of the frame which guides the lower end of the cutting-bar, and gives it great lateral stiffness. The well-known "Whitworth motion" is used to give the tool a more rapid motion during the up stroke than when cutting. A truly-turned cylindrical projection cast on the back of the bracket *K* furnishes a bearing, on which revolves the spur-wheel *A*, driven by the cone *G* and pinion *H*. A bearing for the crank-shaft is bored eccentrically through this projection and the bracket on which it is cast. The pin, sliding block, and grooved crank are arranged in the manner common to motions of this class; the crank, however, being expanded into a light circular disk for neatness of appearance and convenience in finishing. The feeding movements are all actuated by the cam *L* through a rock-shaft and double-slotted arm *P*, in which the stud of the rod *Q* is adjusted to regulate the quantity of feed as desired. The bevel-sector and pinion *S* give motion to the shaft *R* and slotted arm *W*, and, through the short rod, pawl, and ratchet-wheel, to the screw moving the table longitudinally. The stud may be moved to a central position in the arm *W* when it is not desired to use the longitudinal feed. A mitre-gear on the shaft *R*, through the shaft *T*, with arm and pawl, conveys a similar intermittent motion to the spur-wheel *Y*, with which *U* and *V* may be brought into connection by sliding on their respective shafts, actuating, in one case the transverse feed, and in the other the rotating or circular one. The form and position of the cam *L* are such as to cause the positive or forward movement of each of the pawls to take place while the pin of the crank *D* is passing its highest position, the return movement occurring while the tool is cutting. A slight excess in length of stroke over the actual length of cut allows the feed to be accomplished while the tool is above the work; and the use of one or the other end of the double-slotted arm *P* determines the direction in which the pawls will be moving at this point in the revolution. The clamps *X X* have lips which fit into the groove in the edge of the circular table, and serve to give it great steadiness. They are particularly useful when the work is so large as to overhang the table. The adjustment of the sliding surface of the table is effected by taper or wedge-shaped shoes, as at *Z*. These are carefully scraped to a uniform bearing from end to end, and the necessary adjustment is accurately made by a slight turn of the screw.

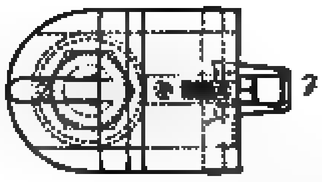
When a slotting-machine cutting tool has its cutting edge standing far down and out from the tool-clamp, the tool springs away from the work; and although this is to a certain extent unavoidable, in many cases it may be allowed for in setting the work upon the table by placing thicknesses of paper beneath the work. The result is that the cut will be parallel with the trued surface of the work, notwithstanding the spring of the tool. This spring, however, has a very damaging effect upon the tool, because the cutting edge presses against the work to the amount of the spring during the back

3950. 3953. 3952.

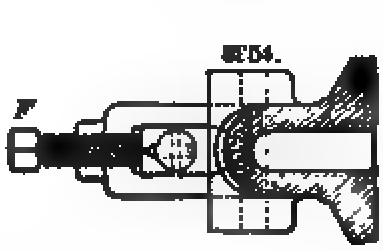
3951.



E



3954.

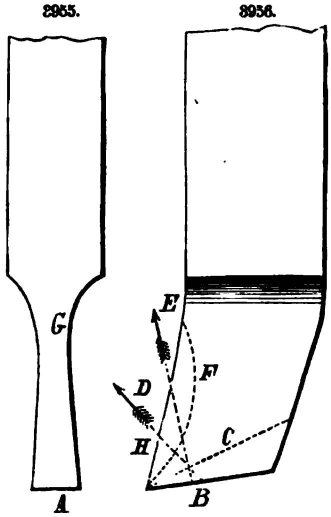


stroke, and that edge therefore becomes more rapidly destroyed. To obviate this, the fixture or device shown in Figs. 3950 and 3951 is furnished to the Bement machine. It is a substantial casting *A* bolted to the cutting-bar, and to this casting is secured a swivel by means of a dovetailed circular projection clamped to the slide. The apron is hinged upon a taper pin *G*, and the tool is secured by a nut *B*, which is threaded on the outside of the tool-post. A spring *C* holds the apron to its place, allowing it to swing slightly downward during the upward stroke.

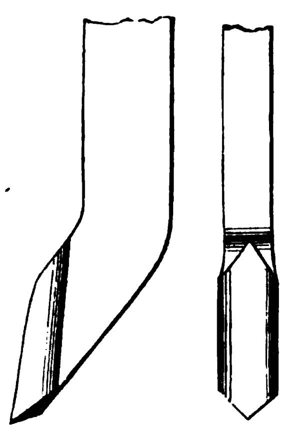
In Figs. 3952, 3953, and 3954 is shown an arrangement used for light work. The steel stock *D* is fitted to the cylindrical socket bored in the steel clamp *E*. A slot is cut through the entire length of one side of the latter, so that the pressure of the screws *F* will hold the stock securely in any position. A "bit" or tool, fitted in the lower end of the stock, is allowed to swing on a hardened taper steel pin sufficiently to relieve the friction during the upward stroke, and is brought into place again by a light spring. In irregular work, in which it is convenient to be able to present the point of the tool in various angular directions, the cylindrical form of stock is advantageous. Very generally, however, a heavy square bar of steel is used, the bits being changed as required. In the tool shown in place in Fig. 3949, the bit is triangular in form, and has the advantage of projecting below the end of the stock. By these devices short and stiff tools may be used and much heavier cuts taken; the work will be more true and finished with a cleaner cut.

Slotting-Machine Tools.—In many cases in slotting machines, long steel tools, such as shown in Figs. 3955 and 3956, are employed. The edge *A* is the cutting edge, the thickness at *G* being reduced to make the sides of the tool well clear the sides of the cut. The face *B* receives the force necessary to bend the shaving or cutting, which force, acting at a right angle to that face, tends to force the tool deeper into the cut at the angle denoted by the dotted line and arrow *E*. Were *B* ground to the angle shown by the dotted line *C*, the force due to bending the shavings or cuttings would be in the direction of the line and arrow *D*. A comparison of *D* and *E* shows that an equal degree of tool-spring would have a greater effect in deepening the tool-cut in the case of *D* than in that of *E*; and it is this consideration which determines the proper angle of the face *B*. It being obvious that the more angle it has the keener the cutting edge of the tool will be, and the greater the liability to force into the cut, and since the deeper the cut the greater is the force required to bend the shavings, the tool continues to spring, digging into the work and either bending or breaking itself, or stopping the machine. Hence the face *B* should be made for slight tools, or for tools held far out from the tool-post, at about the angle shown. The face *H* should in all cases be made as shown, and not hollowed at all in the direction shown by the dotted line *F*, which would not only weaken the tool, but would cause the cutting edge to be badly supported by the metal behind it, and hence to break. These considerations as to the shape and angle of the faces *B* and *H* apply to all descriptions of slotting-machine cutting tools; and they are of more importance in the class of tools here shown

3955. 3956.



3957.



than in tools used in any other kind of machine, because of the great distance they have at times to stand out from the holding screws or clamps.

A roughing-out tool, held in the tool-post without the aid of a bar, should be made as shown in Fig. 3957, concerning which nothing need be said save that it should be hardened right out if the cutting edge stands close to the holding screws or clamps of the tool-post, and tempered to a light straw if held far out from the same, which will, in the latter case, prevent it from breaking in consequence of any deepening of the cut from the tool springing. J. R. (in part).

SOLAR ENGINE. See ENGINE, SOLAR.

SOLDERING. The process of uniting the edges or surfaces of similar or dissimilar metals and alloys by partial fusion. In general, alloys or solders of various and greater degrees of fusibility than the metals to be joined are placed between them, and the solder when fused unites the three parts into a solid mass; less frequently the surfaces or edges are simply melted together with an additional portion of the same metal. The solders are broadly distinguished as *hard solders* and *soft solders*. The former only fuse at red heat, and are consequently suitable alone to metals and alloys which will endure that temperature; the soft solders melt at very low degrees of heat, and may be used for nearly all the metals. To avoid continual repetition, references are made to the lists in the succeeding table, in which some of the solders, fluxes, and modes of applying heat are enumerated.

Hard Soldering.—Applicable to nearly all metals less fusible than the solders; the modes of

treatment nearly similar throughout. The hard solders most commonly used are the spelter solders and silver solders. The general flux is borax; and the modes of heating are the naked fire, the furnace or muffle, and the blow-pipe. Fine gold, laminated and cut into shreds, is used as the solder for joining chemical vessels made of platinum. Silver is by many considered as much the best solder for German silver. Copper in shreds is sometimes similarly used for iron. Gold solders laminated are used for gold alloys. Spelter solders, granulated while hot, are used for iron, copper, brass, gun-metal, German silver, etc. Silver solders laminated are employed for all silver works and for common gold work; also for German silver, gilding-metal, iron, steel, brass, gun-metal, etc., when greater neatness is required than is obtained with spelter solder. White or button solders granulated are employed for the white alloys called button metals; they were introduced as cheap substitutes for silver solder.

Soft Soldering.—Applicable to nearly all the metals; the modes of treatment very different. The soft solder mostly used is 2 parts tin and 1 part lead; sometimes from motives of economy much more lead is employed, and 1½ tin to 1 lead is the most fusible of the group unless bismuth is used. The fluxes B to G, and the modes of heating *a* to *i*, in the table, are all used with the soft solders. The examples commence with the metals to be soldered. Thus in the list, zinc, 8, C, *f*, implies that zinc is soldered with No. 8 alloy, by the aid of the muriate or chloride of zinc and the copper-bit. Lead, 4 to 8, F, *d*, *e*, implies that lead is soldered with alloys varying from No. 4 to 8, and that it is fluxed with tallow, the heat being applied by pouring on melted solder, and the subsequent use of the heated iron not tinned; but in general one only of the modes of heating is selected, according to circumstances.

Iron, cast iron, and steel, 8, B, D, if thick, heated by *a*, *b*, or *c*, and also by *g*.

Tinned iron, 8, C, D, *f*.

Silver and gold are soldered with pure tin or else with 8, E, *a*, *g*, or *h*.

Copper and many of its alloys, namely, brass, gilding-metal, gun-metal, etc., 8, B, C, D; when thick, heated by *a*, *b*, *c*, *e*, or *g*, and when thin by *f* or *g*.

Speculum-metal, 8, B, C, D. The heat should be most cautiously applied; the sand-bath is perhaps the best mode.

Zinc, 8, C, *f*.

Lead and lead pipes, or ordinary plumbers' work, 4 to 8, F, *d*, or *e*.

Lead and tin pipes, 8, D and G mixed, *g*, and also *f*.

Britannia metal, 8, C, D, *g*.

Pewters: the solders must vary in fusibility according to the fusibility of the metal; generally G and *i* are used, sometimes also G and *g*, or *f*.

Tinning the metals, and washing them with lead, zinc, etc.

Soldering per se, or Burning Together.—Applicable to some few of the metals only, and which in general require no flux. Iron, brass, etc., are sometimes burned, or united by partial fusion, by pouring very hot metal over or around them, *d*. Lead is united without solder, by pouring on red-hot lead, and employing a red-hot iron, *d*, *e*, and also by the autogenous process.

Alloys and their Melting Heats.

No. 1.	1 tin, 25 lead	558° F.
2.	1 " 10 "	541
3.	1 " 5 "	511
4.	1 " 3 "	482
5.	1 " 2 "	441
6.	1 " 1 "	370
7.	1½ " 1 "	334
8.	2 " 1 "	340
9.	3 " 1 "	356
10.	4 " 1 "	365
11.	5 " 1 "	378
12.	6 " 1 "	381
13.	4 lead, 4 tin, 1 bismuth	320
14.	3 " 3 " 1 "	310
15.	2 " 2 " 1 "	292
16.	1 " 1 " 1 "	254
17.	2 " 1 " 2 "	236
18.	3 " 5 " 3 "	202

Fluxes.

A. Borax.
B. Sal-ammoniac, or muriate of ammonia.
C. Muriate or chloride of zinc.
D. Common rosin.
E. Venice turpentine.
F. Tallow.
G. Gallipoli oil, a common sweet oil.

Modes of Applying Heat.

a. Naked fire.
b. Hollow furnace or muffle.
c. Immersion in melted solder.
d. Melted solder or metal poured on.
e. Heated iron not tinned.
f. Heated copper tool, tinned.
g. Blow-pipe flame.
h. Flame alone, generally alcohol.
i. Stream of heated air.

The Modes of applying Heat in Soldering.—The modes of heating works for soldering are extremely varied, and depend jointly upon the magnitude of the objects, the general or local manner in which they are to be soldered, and the fusibility of the solders.

In hard-soldered works, the fires bear a general resemblance to those employed in forging iron and steel; in fact, the blacksmith's forge is frequently used for brazing, although the process is injurious to the fuel as regards its ordinary use. Coppersmiths, silversmiths, and others use a similar hearth, but which stands farther away from the upright wall, so as to allow of the central parts of large objects being soldered. The bellows is always worked by the foot, either by a treadle, or more commonly by a chain from the rocking-staff terminating in a stirrup. The brazier's hearth for large and long works is a flat plate of iron, about 4 × 3 ft., which stands in the middle of the shop upon four legs. The surface of the plate serves for the support of long tubes, and works over the central aperture in the plate which contains the fuel, and measures about 2 × 1 ft. and 5 or 6 in. deep. The revolving fan is commonly used for the blast, and the tuyere irons, which have larger apertures than

usual, are fitted loosely into grooves at the ends, to admit of easy renewal, as they are destroyed rather quickly. The fire is sometimes used of the full length of the hearth, but is more generally contracted by a loose iron plate; occasionally two separate fires are made, or the two blast-pipes are used upon one. The hood is suspended from the ceiling, with counterpoise weights, so as to be raised or depressed according to the magnitude of the works; and it has large sliding tubes for conducting the smoke to the chimney.

There are many purposes in the arts which require the application of heat having the intensity of the forge-fire or of the furnace, but with the power of observation, guidance, and definition of the artist's pencil. These conditions are most efficiently obtained by the blow-pipe, an instrument by which a stream of air is driven forcibly through a flame, so as to direct it either as a well-defined cone, or as a broad jet of flame, against the object to be heated, which is in many cases supported upon charcoal, by way of concentrating the heat. Most of the blow-pipes are supplied with common air, and generally by the respiratory organs of the operator; sometimes by bellows moved with the foot, by vessels in which the air is condensed by a syringe, or by pneumatic apparatus with water-pressure. In some few cases oxygen or hydrogen, or the same gases when mixed, are employed. The ordinary blow-pipe is a light conical brass tube, about 10 or 12 in. long, from one-half to one-fourth of an inch in diameter at the end for the mouth, and from one-sixteenth to one-fiftieth at the aperture or jet. The end is bent as a quadrant, that the flame may be immediately under observation. The most intense heat of the common blow-pipe is that of the pointed flame; with a thick wax candle, and a blow-pipe with a small aperture placed slightly within the flame, the mineralogist succeeds in melting small fragments of all the metals, when they are supported upon charcoal and exposed to the extreme point of the inner or blue cone, which is the hottest part of the flame; that is, fragments of all metals which do not require the oxyhydrogen blow-pipe. The first, or the silent pointed flame, is used by the chemist and mineralogist for reducing the metallic oxides to the metallic state, and is called the *deoxidizing* flame; the second, or the noisy, brush-like flame, is less intense, and is called the *oxidizing* flame.

The following method is much employed by the cheap jewelry manufacturers at Birmingham. A stream of air from a pair of bellows directs a gas-flame through a trough or shoot, the third of a cylindrical tube placed at a small angle below the flame. Instead of a charcoal support, they employ a wooden handle, upon which is fixed a flat disk of sheet iron, about 3 or 4 in. diameter, covered with a matting of waste fragments of binding wire, entangled together and beaten into a sheet about three-eighths or half an inch thick; some few of the larger pieces of wire extend round the edge of the disk to attach the remainder. The work to be soldered is placed upon the wire, which becomes partially red-hot from the flame, and retains the heat somewhat as the charcoal, but without the inconvenience of burning away, so that the broad level surface is always maintained. Small cinders are frequently placed upon the tool, either instead of or upon the wire. Sometimes the gas-pipe is surmounted by a square hood, open at both ends, and two blast-pipes are directed through it. The latter arrangement is used by the makers of glass toys and seals; these are pinched in moulds something like bullet-moulds; the devices on the seals are produced by inserting in the moulds dried casts, made in plaster of Paris.

The general form of the "workshop blow-pipe" is that of a tube open at one end, and supported on trunnions in a wooden pedestal, so that it may be pointed vertically, horizontally, or at any angle as desired. Common street gas is supplied through the one hollow trunnion, and it escapes through an *annular* opening; while oxygen gas, or more usually common air, is admitted through the other trunnion, which is also hollow, and is discharged in the centre of the hydrogen through a central conical tube; the magnitude and intensity of the flame being determined by the relative quantities of gas and air, and by the greater or less protrusion of the inner cone, by which the annular space for the hydrogen is contracted in any required degree.

The works in copper, iron, brass, etc., having been prepared for *brazing* (or soldering with a fusible brass), and the joints secured in position by binding-wire where needful, the granulated spelter and pounded borax are mixed in a cup with a very little water, and spread along the joint by a slip of sheet metal or a small spoon. The work, if sufficiently large, is now placed above the clear fire, first at a small distance so as gradually to evaporate the moisture, and likewise to drive off the water of crystallization of the borax; during this process the latter boils up with the appearance of froth or snow, and if hastily heated it sometimes displaces the solder. The heat is now increased, and when the metal becomes faintly red, the borax fuses quietly like glass; shortly after, that is at a bright red, the solder also fuses, the indication of which is a small blue flame from the ignition of the zinc, and is absorbed in the joint. It is of course necessary to apply the heat as uniformly as possible by moving the work about so as to avoid melting the object as well as the solder. The work is withdrawn from the fire as soon as the solder has flushed; and when the latter is set, the work may be cooled in water without mischief. Tubes are generally secured by loops of binding-wire twisted together with the pliers; and those soldered upon the open fire are almost always soldered from within, as otherwise the heat would have to be transmitted across the tube with greater risk of melting the work, air being a bad conductor of heat; it is necessary to look *through* the tube to watch for the melting of the solder. Long tubes are rested upon the flat plate of the brazier's hearth, and portions equal to the extent of the fire are soldered in succession. The common tubes for gas-works, bedsteads, and numerous other purposes, are soldered from the outside; but this is done in short furnaces open at both ends and level with the floor, by which the heat is applied more uniformly around the tubes.

Works in iron require much less precaution in point of the heat, as there is little or no risk of fusion. Thus in soldering the spiral wires to form the internal screw within the boxes of ordinary tail-vises, the work is coated with loam, and strips of sheet brass are used as solder; the fire is urged until the blue flame appears at the end of the tube, when the fusion is complete; the work is with-

drawn from the fire and rolled backward and forward on the ground to distribute the solder equally at every part. Other common works in iron, such as locks, are in like manner covered with loam to prevent the iron from scaling off. Sheet iron may be soldered by filings of soft cast iron, applied in the usual way of soldering with borax, which has been gradually dried in a crucible and powdered, and a solution of sal-ammoniac.

The finer works in iron and steel, those in the light-colored metals generally, and also the works in brass which are required to be very neatly done, are soldered with silver solder. The practice of silver-soldering is essentially the same as brazing. The joint is first moistened with borax and water; the solder (which is generally laminated and cut into little squares with the shears) is then placed on the joints with forceps.

In soldering gold and silver, the borax is rubbed with water upon a slate to the consistence of cream, and is laid upon the work with a camel's-hair pencil, and the solders, although generally laminated, are also drawn into wire or filed into dust; but, it will be remembered, the more minute the particles of the granulated metals the greater is the degree of heat required in fusing them.

Examples of Soft Soldering.—In this section the employment of the less fusible of the soft solders will be first noticed. The plumbers' sealed solder, 2 parts lead and 1 part tin, melts at about 440° F.; the usual or fine tin-solder, 2 parts tin and 1 part lead, melts at 340°; and the bismuth-solders at from 250° to 270°. The modes of applying the heat consequently differ very much, as will be shown.

Lead works are first smeared or soiled around the intended joints with a mixture of size and lamp-black, called *soil*, to prevent the adhesion of the melted solder. Next the parts intended to receive the solder are shaved quite clean with the *shave-hook* (a triangular disk of steel riveted on a wire stem), and the clean metal is then rubbed over with tallow. Some joints are *wiped*, without the employment of the soldering iron; that is, the solder is heated rather beyond its melting-point, and poured somewhat plentifully upon the joint to heat it. The solder is then smoothed with the cloth, or several folds of thick bed-tick well greased, with which the superfluous solder is finally removed. Other lead joints are *striped*, or left in ridges, from the bulbous end of the plumber's crooked soldering-iron, which is heated nearly to redness, and not tinned. The iron and cloth are jointly used at the commencement for moulding the solder and heating the joint. In this case less solder is poured on, and a smaller quantity remains upon the work; and although the striped joints are less neat in appearance, they are by many considered sounder from the solder having been left undisturbed in the act of cooling. The vertical joints, and those for pipes, whether finished with the cloth or iron, require the cloth to support the fluid solder when it is poured on the lead. Slight works in lead, such as lattices, requiring more neatness than ordinary plumbing, are soldered with the *copper-bit* or *copper-bolt*—a piece of copper weighing from 3 or 4 ounces to as many pounds, riveted into an iron shank and fitted with a wooden handle. All the works in tinned iron, sheet zinc, and many of those in copper and other thin metals, are soldered with this tool, which in general suffices to convey all the heat required to melt the more fusible solders now employed. If the copper-bit have not been previously tinned, it is heated in a small charcoal stove or otherwise to a dull red, and hastily filed to a clean metallic surface; it is then rubbed immediately, first upon a lump of sal-ammoniac, and next upon a copper or tin plate, upon which a few drops of solder have been placed; this will completely coat the tool; it is then wiped clean with a piece of tow, and is ready for use.

In soldering coarse works, when their edges are brought together they are slightly strewed with powdered rosin, or it is spread on the work with a small spoon; the copper-bit is held in the right hand, the cake of solder in the left, and a few drops of the latter are melted along the joint at short intervals. The iron is then used to heat the edges of the metal, both to fuse and to distribute the solder along the joint, so as entirely to fill up the interval between the two parts. Only a short portion of the joint, rarely exceeding 6 or 8 inches, is done at once. Sometimes the parts are held in contact with a broad chisel-formed tool, or a hatchet stake, while the solder is melted and cooled, or a few distant parts are first *tacked* together or united by a drop of solder; but mostly the hands alone suffice without the tacking. Two soldering tools are generally used, so that while the one is in the hand the other may be reheating in the stove. The temperature of the bit is very important; if it be not hot enough to raise the edges of the metal to the melting heat of the solder, it must be returned to the fire. Unless by mismanagement it is made too hot and the coating is burned off, the process of tinning the bit need not be repeated; it is simply wiped on tow on removal from the fire. If the tool be overheated, it will make the solder unnecessarily fluid, and entirely prevent the main purpose of the copper-bit, which is intended to act both as a heating tool and as a brush, first to pick up a small quantity or drop from the cake of solder which is fixed upright in a tray, and then to distribute it along the edge of the joint.

Copper works are more commonly fluxed with powdered sal-ammoniac, and so likewise sheet iron, although some mix powdered rosin and sal-ammoniac. Others moisten the edges of the work with a saturated solution of sal-ammoniac, using a piece of cane, the end of which is split into filaments to make a stubby brush, and they subsequently apply rosin. Each method has its advocates, but so long as the metals are well defended from oxidation any mode will suffice, and in general management the processes are the same.

Zinc is more difficult to solder than the other metals, and the joints are not generally so neatly executed. The zinc seems to remove the coating of tin from the copper soldering tool; this probably arises from the superior affinity of copper for zinc than for tin. The flux sometimes used for zinc is sal-ammoniac, but the muriate of zinc, made by dissolving fragments of zinc in muriatic acid diluted with about an equal quantity of water, is much superior; and the muriate of zinc serves admirably likewise for all the other metals, without such strict necessity for clean surfaces as when the other fluxes are used.

Small works are sometimes united by cleaning the respective surfaces, moistening them with sal-ammoniac water, or applying the dry powder or rosin, then placing between the pieces a slip of tin

foil previously cleaned with emery-paper, and pinching the whole between a pair of heated tongs to melt the foil; or other similar modifications combining heat and pressure are used.

Tinning.—Iron, copper, and alloys of the latter metal, are frequently coated with tin, and occasionally with lead and zinc, to present surfaces less subject to oxidation. Gilding and silvering are partly adopted from similar motives.

Copper and brass vessels are first pickled with sulphuric acid, mostly diluted with about three times its bulk of water; they are then scrubbed with sand and water, washed clean, and dried; they are next sprinkled with dry sal-ammoniac in powder, and heated slightly over the fire; then a small quantity of melted block tin is thrown in, the vessel is swung and twisted about to apply the tin on all sides, and when it has well adhered the portion in excess is returned to the ladle, and the object is cooled in water. When cleverly performed, very little tin is taken up, and the surface looks almost as bright as silver. Some objects require to be dipped into a ladleful of tin.

The proportions of nickel and iron mixed with the tin in order to produce the best tinning are 10 oz. of the best nickel and 7 oz. of sheet iron to 10 lbs. of tin. These metals are mixed in a crucible; and to prevent the oxidation of the tin by the high temperature necessary for the fusion of the nickel, the metals are covered with 1 oz. of borax and 3 oz. of pounded glass. The fusion is completed in about half an hour, when the composition is run off through a hole made in the flux. In tinning metals with this composition, the workman proceeds in the ordinary manner.

There is also another method, that of *cold tinning*, by aid of the amalgam of mercury; but this process, when applied to utensils employed for preparing or receiving food, appears questionable both as regards effectiveness and wholesomeness, and the activity of the muriatic acid must not be forgotten; it should be therefore washed carefully off with water. The tin adheres, however, sufficiently well to allow other pieces of metal to be afterward attached by the ordinary copper soldering-bit.

Soldering per se, or Burning Together.—This principally differs from ordinary soldering, in the circumstance that the uniting or intermediate metal is the same as those to be joined, and that in general no fluxes are employed.

Pewter is sometimes burned together at the external angles of works, simply that no difference of color may exist; the one edge is allowed to stand a little above the other, a strip of the same pewter is laid in the angle, and the whole are melted together, with a large copper-bit heated almost to redness; the superfluous metal is then filed off, leaving a well-defined angle without any visible joint

Brass is likewise burned together. For instance, the rims of the large mural circles for observatories, that are 5, 6, or 7 ft. diameter, are sometimes cast in six or more segments, and attached by burning. The ends of the segments are filed clean, two pieces are fixed vertically in a sand-mould in their relative positions, a shallow space is left around the joint, and the entire charge of a crucible, say 30 or 40 lbs. of the melted brass, a little hotter than usual, is then poured on the joint to heat it to the melting-point. The metal overflows the shallow chamber or hole, and runs into a pit prepared for it in the sand; but the last quantity of metal that remains solidifies with the ends of the segments, and forms a joint almost or quite as perfect as the general substance of the metal. The process is repeated for every joint of the circle.

The compensation-balance of the chronometer and superior watches is an interesting example of natural soldering. The balance is a small fly-wheel made of one piece of steel, covered with a hoop of brass. The rim, consisting of the two metals, is divided at the two extremities of the one diametrical arm of the balance, so that the increase of temperature which weakens the balance-spring contracts in a proportionate degree the diameter of the balance, leaving the spring less resistance to overcome. This occurs from the brass expanding much more by heat than steel, and it therefore curls the semicircular arc inward, an action that will be immediately understood if we conceive the compound bar of brass and steel to be straight, as the heat would render the brass side longer and convex, and in the balance it renders it more curved. In the compensation-balance, the two metals are thus united: The disk of steel, when turned and pierced with a central hole, is fixed by a little screw-bolt and nut at the bottom of a small crucible, with a central elevation smaller than the disk; the brass is now melted and the whole allowed to cool. The crucible is broken, the excess of brass is turned off in the lathe, the arms are made with the file as usual, the rim is tapped to receive the compensation screws or weights, and lastly the hoop is divided in two places at opposite ends of its diametrical arm. A little black lead is generally introduced between the steel and the crucible; and other but less exact modes of combining the metals are also employed.

Cast iron is likewise united by burning, as will be explained by the following example: To add a flange to an iron pipe, a sand-mould is made from a wood model of the required pipe, but the gusset or chamfered band between the flange and tube is made rather fuller than usual, to afford a little extra base for the flange. The mould is furnished with an ingate, entering exactly on the horizontal parting of the mould, at the edge of the flange, and with a waste-head or runner proceeding upward from the top of the flange, and leading over the edge of the flask to a hollow or pit sunk in the sand of the floor. The end of the pipe is filed quite clean at the place of junction, and a shallow nick is filed at the inner edge to assist in keying on the flange. Lastly, the pipe is plugged with sand and laid in the mould. After the mould is closed, about six or eight times as much hot metal as the flange requires is poured through the mould; this heats the pipe to the temperature of the fluid iron, so that on cooling the flange is attached sufficiently firm to bear the ordinary pressure of screw-bolts, steam, etc.

The method of burning is occasionally employed in most of the metals and alloys, in making small additions to old castings, and also in repairing trifling holes and defects in new ones. It is only successful, however, when the pieces are filed quite clean, and abundance of fluid metal is employed, in order to impart sufficient heat to make a natural soldering. This process is also employed in plating copper with silver, although differently accomplished, as the two metals are raised to a heat just short of the melting-point of the silver, and the metals then unite without solder by partial alloying.

SOWING MACHINE. See Agricultural Machinery.
SPECIFIC GRAVITY. See Gravity, Specific.
SPINDLES. See Cotton-spinning Machinery, and Millstones.
SPINNING MACHINERY. See Cotton-spinning Machinery, Flax, Machinery for Preparation of, etc., and Silk-spinning Machinery.

SPINNING METAL. The term spinning is given to a process for altering the shape of malleable metals, by causing sheet metal to conform or flow into hemispherical, oval, or irregular forms by motion and pressure. The operation is considered more advantageous than stamping, because it acts more kindly on the metal. It is the result of gentle pressure combined with rapid motion, and involves a great principle—the effect due to motion in connection with time. The chief feature in all such changing of form is the giving of sufficient time for the particles to move or flow. To press the flow too rapidly would cause the sheet to tear from rupture of particles. This tendency to tear is defeated by communicating a very rapid circular motion to the sheet of metal, and then, by means of an instrument held in the hand, a gentle pressure is caused to bear on one point, thus producing a slight depression; but as the sheet is spinning at high velocity, the depression at once forms a circle, and so, by continuing the pressure of the instrument, it is moulded into any form accordingly.

3958.

3959.

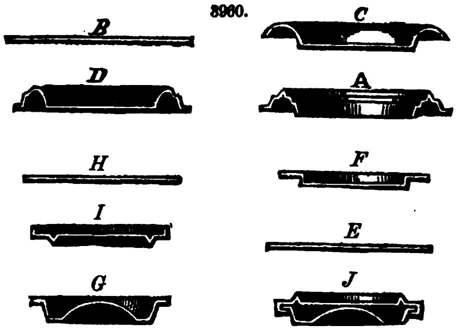
The operation of spinning, as represented in Fig. 3958, is performed in a species of lathe. A mould of the required form is fixed on the face-plate of the revolving spindle; the sheet or disk of metal is held by pressure from another head-stock against the mould, and by the local pressure of the instrument is thus adroitly formed to the shape of the latter. Instead of a solid mould, in forming the bowls of teapots and other hollow ware, sectional chucks of metal, represented in Fig. 3959, are used. Over these the entire body of a teapot or cup may be moulded. One core of the chuck being removed, the remainder can be taken out in sections.

Fig. 3960 represents a powder-case during different stages of spinning. *A* is the completed stationary portion, which has reached its present peculiar shape after passing through five stages. It is first cut into the flat disk *B*; then the disk is spun as far as *C*; it now requires to be annealed, and after this it is turned into the third condition; it is then spun into the fourth stage *D*, and from that to the finished article *A*. The lid, which fits into *A*, is composed of two separate pieces, both made by spinning from disks, and both pieces when completed are united by spinning over a lap of one

upon the other. The disk E is brought to the form F, and then to that shown in G. Disk H is spun into the form I. The forms I and H combined produce the finished lid J.

The French, who were the originators of the process, employ it with great dexterity in a variety of ways, more especially in the production of such articles as large oval dish-covers. The sheet is secured to the centre of an oval chuck, and by a dexterous use of two pieces of greased boxwood, held in both hands, the workman very cleverly prevents the sheet from puckering as he spins it into an oval, and finally turns over the outer edge into a border, thus giving it rigidity as well as neat finish.

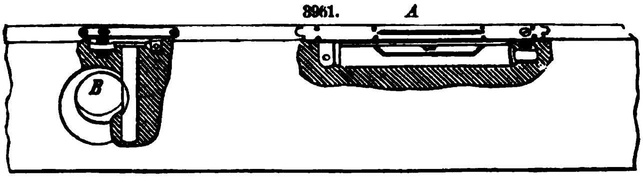
3960.



See "Lecture on Metal-Spinning," by John Anderson, C. E., in the *Scientific American*, xxi., 370. Metal-spinning as applied to silver-ware is described in the *Scientific American*, xxxvi., 287, and to plated ware in *Appletons' Journal*, December, 1878.

SPIRIT-LEVEL. A frame of metal or wood, the upper and lower faces of which are straight and parallel one with the other, into the body of the stock of which is inserted a small glass tube containing alcohol. The spirit does not entirely fill the tube, and hence, when the tube is hermetically sealed, there will be shown therein a small air-bubble. The tube is set so that when the true faces stand exactly horizontal, the bubble will appear in the middle of the length of the tube. When the true face of the implement is placed against the work, the position of the bubble denotes the horizontal position of the work. In the spirit-level shown in Fig. 3961 two glass tubes are inserted, at A and B. These are placed relatively at right angles to one another, and serve for both vertical and horizontal verification. Spirit-levels are also constructed with a rotating spirit-tube, the amount of rotation of which is measured on a graduated scale, so that the level is thus converted into an inclinometer.

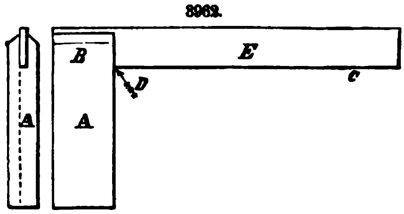
3961.



SPOOLING MACHINE. See COTTON-SPINNING MACHINERY.

SQUARE. An instrument composed of two arms, one of metal and the other of wood, or both of metal, disposed at an exact right angle. Its object is to determine the adjustment of pieces at 90°, or to lay off work. Fig. 3962 represents a machinist's square of proper proportions. The metal portion or blade E should be of saw-plate. The back A is made in halves as indicated by the dotted line, one portion having a recess as shown to receive the blade. The parts are secured by rivets.

3962.



SQUEEZER. See IRON-WORKING MACHINERY—PUDDLING.

STAIR-BUILDING. See CARPENTRY.

STAMPS, ORE. The ore-stamp is the simplest and most effective machine for crushing ores to powder. Breakers and rolls (see BREAKER OR CRUSHER) act by direct slow pressure, while stamps in falling acquire momentum and strike quick sharp blows upon the mass to be broken. The whole stamp is composed of the following parts: the stem, the tappet, the stamp-head or socket, and the shoe. The mass of hardened iron on which the stamp-head falls is called the die, and this is placed in a cast-iron box called the mortar.

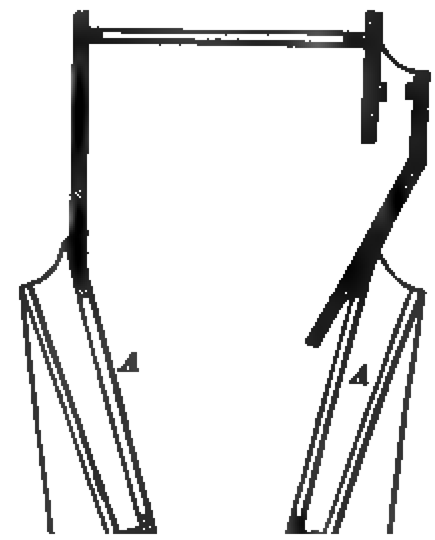
The arrangements of the various parts of a stamp-battery will be understood from Fig. 3963, which represents Stanford's patent self-feeder, manufactured by Messrs. Prescott, Scott & Co. of San Francisco. A is the stamp-stem, on which is keyed a feeding-tappet B. This tappet is so set on the stem, that when the rock on the die has been reduced to a certain depth, it shall in falling with the stamp strike on one end of the lever C. This lever is hung from the girt K, and is forked so that it spans the stamp-stem. The rod E passes up through a hole in the outside end of the lever, and has a collar bearing against the lever to support it. The height of this collar is regulated by a screw and check-nuts F on the lower end of the rod E. A rod D, with a hook at each end, engages a notch in the lever C, and also hooks into the bail of the shoe G of the hopper-car H. The shoe is hinged at L. The hopper-car is lined with sheet iron, and has four wheels, so that when the battery is to be operated without the self-feeder, it can be run out of the way. The operation of the apparatus is as follows: The feeding-tappet B having been clamped on the stem, and the lever having been regulated to its proper position for the distances apart at which the shoe and die are to work by reason of the intervening material, the hopper-car is filled with rock. The mortar is first fed by hand, so as to make a bed under the stamps. As soon as the rock under the middle stamp, to which the feeding-tappet is attached, decreases in depth below the fixed limit, the feeding-tappet in its descent strikes against the lever C, and through the rod D jars the shoe G, causing it to throw a quantity

of rock into the mortar. This continues until the rock has become so thick under the stamp that the feeding-tappet does not touch the lever. Feeding is then stopped, to begin again when the rock has been crushed from under the stamp. The feed is adjusted to the wear of the shoes and dies by the screw F, and by moving the feeding-tappet B on the stem.

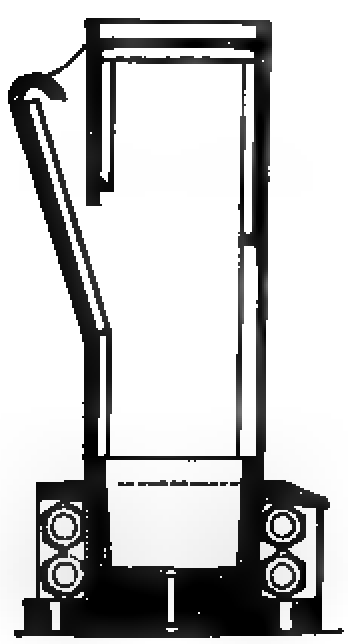
MORTARS.—In the old-fashioned batteries the mortar or coffer in which the stamps act is made of plank, bolted to a timber frame, lined with sheet iron, and fitted with a cast-iron bed or shallow

3963.

3964.



3965.



trough at the bottom, which serves as the die or anvil. But in working gold ores it becomes of the first importance to prevent all leakage in the batteries, especially where quicksilver is used. With wooden mortars this is next to impossible, especially if they are allowed to become dry; and besides, it is difficult to construct them in the best form. Cast-iron mortars fulfill all required conditions, and these are therefore in general use. They are constructed so as to be adapted to the peculiar conditions of their employment. The mortar for dry crushing is suitable either for gold or for silver ore, while for wet crushing the gold differs from that used for silver. When machinery is to be transported to localities which are inaccessible to wagons, mortars are made in sections and fastened together permanently after being put in place.

Figs. 3964 and 3965 represent the dry mortar in solid and in sectional form. The die is set as high as in the wet mortar for gold. The screens at A are more inclined from the perpendicular than those of wet mortars, and there is a double discharge. The width of the bottom upon which the die is set is about 11 in. for a die of 8 in. diameter, while the outside length is about 52 in.

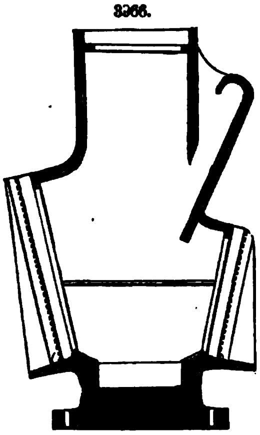
In the sectional mortar, Fig. 3965, the upper part is made of boiler-plate, fastened at the corners by angle-iron. The bed is of cast iron in sections cut transversely. A bar of wrought iron is fitted into a groove planed in the bottom, with rivets holding it securely to the sections. This prevents any sideway working of the sections, which are firmly bolted together.

Wet-crushing mortars for gold and silver respectively are represented in Figs. 3966 and 3967. The mortar for gold, together with its screen doors, is lined with copper. The discharge is above the lining. The general shape of the silver mortar for wet crushing is almost identically that of the gold mortar. The die, however, is set lower, while the screens, for which openings are made on each

side, are brought nearer to the middle line of the stamp, and have their whole surface available for discharge.

Cams, which lift the stem by means of the tappet, are made, as is shown in Figs. 3968 and 3969, either with one or two arms. The single-armed cam will permit greater speed of stamp than the double-armed cam. It will work up as high as 110 drops per minute. The great majority of mills use double-armed cams, in order to avoid friction of the cam-shaft, since they give two drops of the stem to every revolution of the shaft. The proper curve of the cam is a modified involute of a circle, the radius of which is equal to the horizontal distance between the centre of the cam-shaft and the centre of the stamp-stem. The modification of this curve consists in giving a sharper curvature than the involute near the end. This form of cam takes the weight of the stamp at the least practicable distance from the centre of the cam-shaft, where the lifting motion is slow and the concussion comparatively slight, and leaves it in such a way, on account of the quickened curve, as that the point of the cam shall not tear along the face of the tappet from a line through its centre to its outer edge or point of delivery. The outer end is shaped to conform to the edge of the tappet. As the curve of the cam is determined by the distance between the centres of the cam-shaft and the stem in the erection of the machinery, this distance should be strictly adhered to in order to insure the satisfactory working of the cam.

3966.



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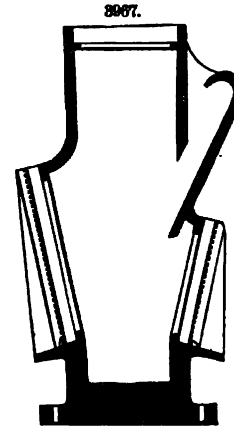
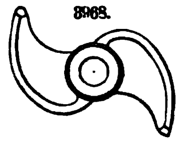


3968.



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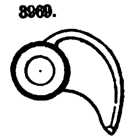
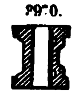
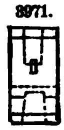


The Tappet, or Lifter, as it is sometimes called, is secured upon the upper part of the stem, and forms a projection 2½ in. wide, under which the cam catches and lifts the stamp. Fig. 3970 is a vertical section of the tappet. It is made of cast iron, and weighs from 60 to 70 lbs. It is alike at both ends, so that when one face becomes worn it can be reversed upon the stem. Formerly the tappets were attached to the stems by means of screw-threads cut upon the latter, the tappet being screwed down as a nut upon a bolt; afterward key-seats were cut to receive the transverse key; but these methods have been superseded by a much more simple and convenient device of a wrought-iron gib, set up against the stem by keys, which has given the name of "gib-tappet" to the improved form. The tappet is cast with a rectangular recess in one side of the hole, for the stem. Into this recess a gib is placed. This is a rectangular block of wrought iron, flat on one side but hollowed on the other, so as to fit the curvature of the stem. Two transverse slots or openings at the back of the recess are provided for keys or wedges, by which the gib is wedged powerfully against the stem, so that the tappet is firmly secured at any desired angle. Thus no key-seat or change of the form of the stem is required, and the tappet can at any time be removed without difficulty merely by driving out the keys.

3970.



3971.



The Stamp-Head or Socket, shown in Fig. 3971, is cylindrical and made of the toughest cast iron, sometimes strengthened with wrought-iron bands at the top and bottom, shrunk in while hot. It is cast with two conical openings or sockets, one in each end, the upper one being for the reception of the tapered end of the stem, and the lower and larger opening for the shank of the shoe. Transverse rectangular openings, or keyways, are made through the socket at the bottom of each end opening. These are for the purpose of driving out the shoe, or of detaching the socket from the stem, by inserting steel keys or wedges, which bear against the end of the stem or of the shoe, and when driven in separate the one from the other. With proper care, the socket wears four years, and after being once attached to the stem need not be removed; but the shoe wears out in a few weeks.

Shoes and Dies.—The form of the shoe is shown in Fig. 3972, and the die in Fig. 3973. Both are cylindrical, and are cast of the hardest and toughest white iron. The shoe is usually 8 in. in diameter and 6 in. in height from the face to the shank. The die corresponds in diameter at the face, but is often made with a broader face than the shoe; its base is either a rectangular flange with its corners taken off, or it is round throughout its whole length, and seated into a socket in the bottom of the mortar.

3972.

3973.

The different parts of the stamp are generally disconnected when shipped, since their construction permits of their being united with ease when they are to be placed in the battery. In order to fasten on the tappet, it is only necessary to slip it on the stem and then wedge it fast by means of the gib and keys. To attach the stamp-head to the stem, the socket is placed upon the die in the mortar and the stem is dropped into it.

The Cam-Shaft is usually made 4½ in. in diameter for five stamps, and sometimes 5 in. for run-

ning ten stamps, with a bearing at each battery post. The pulley on its end is made of wood, built on flanges. The cams are keyed on by either one or two keys each.

The Guides, in which the stamp-stem is run, are generally made of the firmest wood that can well be obtained; and they are secured to the girts of the battery-frame by collar-bolts between each two stems. They are constructed in halves, so that when worn by the stem they may be closed up to it by dressing down their faces.

The Screen, for working ores by the wet process, is made generally of Russia sheet iron. This iron has a planished, glossy, and smooth surface; it should be free from rust or flaws, and be very soft and tough. The severest test of sheet iron consists in hammering a part of the sheet into a concave form. In the manufacture of this kind of screens, the sheet is perforated by punches, varying in size from the number 0 to the number 10 common sewing needle. The screen for the working of ores dry is usually made of wire, and varies in fineness from 900 to 10,000 meshes to the square inch.

The Ball Ore-Stamp, represented in a full-page plate and in detail in Figs. 3974 to 3981, is an overhead stamp of great power, of improved modern construction. *A A* are the bed-timbers, surrounded by cast-iron sills *B*, over which are placed timbers *C* and *D*. The timbers *E* support the battery-posts, and at *G* is the bed-plate of the mortar. The battery-posts are held together by a wooden cap

3974.

f at the top, and by the iron frame *N*, the bunter-beam *V*, and the cheek-pieces *T*. They are braced by iron beams *G*. The mortar proper, *a*, Fig. 3976, is cast in one piece and weighs 1,500 lbs. It is shown in plan in Fig. 3978. On the mortar bottom is placed the bed-plate *c*, and above this the die proper *d*. The die is surrounded by a ring *e*, fastened to the bed-plate by the bolts *f*, as shown in Fig. 3977. At *g* are the stave-linings, of hard chilled cast iron, held in place by mutual contact

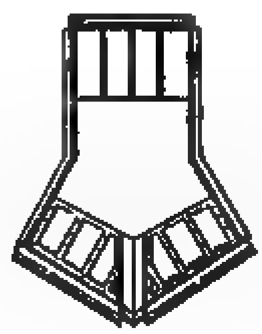
THE BALL ORE-STAMP.

and the bolt *h*. Above these are the side linings *m* and *n*, the lower ones of cast, the upper ones of wrought iron. The mortar linings are changed about once a year. The shoes *p*, Fig. 3976, are made circular with the sides cut off. On the upper side they have a projecting piece, one side of which is dovetailed to fit into the slot of the stem. They weigh from 450 to 650 lbs., and are of hard cast iron.

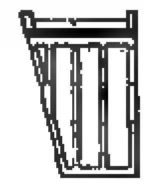
The mortar with straight sides, instead of flaring ones as above described, is shown in Fig. 3981, the various parts already named being similarly lettered. At *g* is the stem. When the front of the mortar flares, there are two screens, each nearly the same size as the back screen, the shape of which is shown in Figs. 3978, 3979, and 3980. These screens are of steel plate three-thirty-seconds of an inch thick, with holes ranging from three-thirty-seconds to three-sixteenths of an inch in diameter.

The screens discharge into hoppers, *L*, Fig. 3974, and *z*, Fig 3976, attached to the inclined sides of the mortar, and deliver the material to launders, which carry the crushed ore to the washers. The top of the mortar is closed. On it is the feed-hopper *W*, Fig. 3976. The stem of the mortar passes through an urn-shaped appendage, *J*, Fig. 3974, and *u*, Fig. 3976, with a cone in the centre, through which water is discharged into the mortar by the pipe *M*. Just above the mortar an iron frame, *N*, Fig. 3975, is bolted to the battery-post *F*, which has two boxes, *O O*, through which the stem of the stamp *P* is guided. Between these two boxes a pulley with feathers, *Q*, is clamped, which works in

3978.

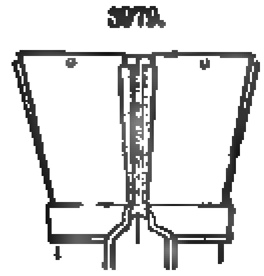


3980.



3981.

3979.



splines in the stamp-stem; a belt running over this pulley gives a rotary motion to the stamp. The stamp-stem *P* is round, and made of wrought iron. Its lower end has a dovetail to receive the shoe, which is fitted and keyed into it. The upper end has a circular flange, to which the bonnet *R* is bolted. At the top of the mortar-frame the steam-cylinder *S* is bolted to a cast-iron frame *T*, which is fitted and bolted to the stamp-frame. The piston passes down through the bunter-beam *V*, which is bolted to the battery timbers, into the bonnet *R*, into which it is screwed, as shown in Fig. 3975. The bunter-beam frame contains a cushion, against which the top of the stamp-shaft bonnet *R* strikes when raised too high, and this prevents its upward motion, and also prevents the piston from knocking the cylinder-head out. It never touches except when too much steam is let into the steam-cylinder, or when the pressure of the boiler is unnecessarily increased. The steam-chest *W* incloses the slide-valve; the steam enters the steam-chest *W* by a pipe *Y*, and is discharged by the exhaust-pipe. The slide-valve works entirely independent of the stamp-stem, running a fixed number of strokes per minute, and is driven by the eccentric *b* and valve-rod *Z*. The eccentric has its motion from a belt on the pulley *c*, which is driven by a separate engine. It runs upon the shaft *d*, upon which are two eccentric elliptical cog-wheels, *e*. The regular motion of the shaft *d* is in this way changed into an irregular motion, and gives the eccentric and steam-valve a slow upward and quick downward movement. By the arrangement of cushions in the stamp-shaft bonnet *R*, the piston-rod and head are relieved from the very severe strain which would otherwise come on them. The mortar of this stamp is so large that the shoe and die must never come together, as the power of the blow is very great. A lever is attached to the side of the stamp, which the bonnet *R* strikes when the rock gets too low, and warns the workmen before the shoes and dies come together

To work the stamp, the motion is communicated to the valve by the pulley *c*, the ore having first

been thrown into the feed-hoppers. It falls down into the mortar proper through the feed-spout W, Fig. 3976. The water is turned on to the pipe M, Figs. 3974 and 3975, and at each blow of the stamp the water and crushed ore are thrown toward the top of the screens. The pulp is forced through the screens, and falls through the spout z into the launders leading to the washers.

A detailed description of the Ball stamp will be found in the *Metallurgical Review*, ii., 4, from which the foregoing is abridged.

Stamp-Mill Performances.—Three Ball's stamps at the Pewabic mill, Lake Superior, running from Jan. 1 to Dec. 31, 1875, gave the following results: No. of days running, 281¾; tons of rock stamped, 53,942; tons stamped per cord of wood, average, 10.84; total running expenses, $46,208.37; cost of stamping and washing one ton of rock, $0.79.

The following table shows sizes and dimensions of these stamps:

Dimensions, etc., of Ball's Ore-Stamps.

NO. OF STAMP.	Diameter of Shaft or Stem, in Inches.	Weight of Stamp-Shaft and Shoe, in Lbs.	Extreme Stroke or Lift, in Inches.	Diameter of Steam-Cylinder, in Inches.	Number of Blows per Minute.	Horse-Power required for one Head.	Actual Amount of Rock Crushed per day of 24 Hours.
1......	8	4,500	28	12 to 15	90	60	120
2......	7	3,500	28	11	90	52	96
3......	6	2,500	26	9	95	35	65
4......	5	1,500	24	8	110	16	35
5......	4	650	18	6	120	8	15 to 20

The following table, compiled from data gathered by Messrs. Prescott, Scott & Co. of San Francisco, relative to performances of the Stanford stamp, shows that heavy stamps, working at a high speed with a short drop, will do more work than lighter stamps at a lower speed with a higher drop. The practice of millmen is inclining in this direction.

Table showing Performances of Stanford Stamp-Batteries.

DATA.	Stanford Mill, White Pine, Nev.	Meadow Valley Mill, Pioche.	Raymond & Ely Mill, Pioche.	International Mill, White Pine.	International Mill, White Pine.	Keystone Consolidated Mill, Amador Co., Cal.	Hunter's Valley Mill, Mariposa Co., Cal.	St. Lawrence Mill, Newcastle, Cal.	Eureka Mill, Virginia City.
Kind of mill............	Silver, dry.	Silver, wet.	Silver, dry	Silver, dry.	Silver, wet.	Gold, wet.	Gold, wet.	Gold, wet.	Silver, wet.
No. of mortars............	6	6	6	6	6	8	6	1	12
Discharge of mortars......	D'ble.	Double.	D'ble.	D'ble.	Double.	Single.	Single.	....	......
No. of stamps to each mortar..............	5	5	5	5	5	5	4 with 4 2 " 6	6	5
Total No. of stamps.......	30	30	30	30	30	40	28	6	60
Weight of stamp in lbs....	750	750	750	750	750	750	650	650	950
Height of drop in inches...	8	9	8	7.5	7.5	8.5	11	10	9
No. of drops per minute...	95	85	95	98	87	85	70	90	93
Screens made of.........	Brass wire.	Russia iron, punched.	Brass wire.	Brass wire.	Russia iron, punched.	Russia iron, slotted.	Russia iron, punched.	Russia iron, punched.	Russia iron, punched.
Trade No. of screens......	50	6	50	50	6	5	6	5	4
Tons of rock crushed in 24 hours............	52	67	48	33	47	90	50	17	159
Tons of rock crushed per stamp in 24 hours.	1.73	2.07	1.6	1.1	1.57	2.25	3.58*	2.85	2.65
Quality of rock formation	Hard l'stone	Tough quartz.	Easy quartz	Soft l'stone	Soft limestone.	Medium quartz.	Easy quartz.	Brittle quartz.	Easy quartz.
Fineness of the bullion....	998	550	775	990	990	840	......	......	950

STARCHING MACHINE. See LAUNDRY MACHINERY.

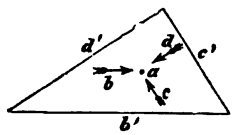
STATICS. That branch of mechanics which treats of the action of forces in equilibrium. The union of two or more forces to produce a mechanical effect is called a composition of forces. Conversely, when a single force is replaced by two or more forces which produce the same effect, or when it is resolved into components for the purpose of mathematical analysis, such operation is called a resolution of forces. Analyses of cases must have regard to: 1, the quantity or intensity of the force or power; 2, the direction in which the force acts; and 3, the part of the body or load to which it is applied, and which is called the point of application. The quantity of force or power is usually expressed by assigning it a value in weight. It may also be represented by a straight line of proportionate length.

Two or more forces acting in the same direction produce a result equal to their sum; acting in opposite directions, the result is a force equal to their difference. When two forces act together to produce a third, they may be represented by two sides of a triangle, while the resultant is represented by the third side. If a point is kept at rest by the action of three forces, these forces may be represented in quantity and direction by the sides of a triangle. Thus, the point a, Fig. 3982, will be kept at rest when acted upon by three forces in the direction of the arrows b, c, and d, where the forces are represented respectively in quantity and direction by the sides b', c', and d'. If the adjacent sides of a parallelogram represent two forces in quantity and direction, the resultant forces will always be represented by the diagonal contained between them. Thus, if $c\,a$ and $c\,d$, Fig. 3983, represent two forces equal in quantity, having the direction shown by the arrows, their resultant will

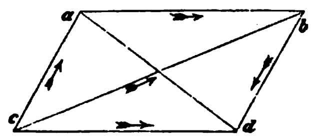
* In 4-stamp mortars, 1.75; in 6-stamp mortars, 1.83.

be represented by the longer diagonal $c\,b$; but if $a\,b$ and $b\,d$ represent two forces acting in the direction of the arrows, the resultant will be represented by the shorter diagonal $a\,d$. These propositions may be experimentally verified by the method of Gravesande. Let two weights of 8 and 10 lbs. be suspended over two friction-pulleys by a string, as shown in Fig. 3984, and let a third weight of say 14 lbs. be suspended from this string, between the pulleys. After a time the system will come to rest. If now the string supporting the middle weight

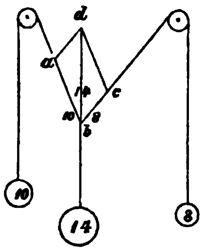
3982.



3983.



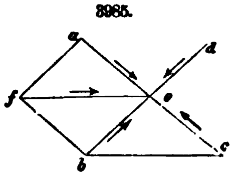
3984.



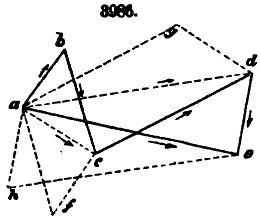
be extended upward vertically to some point as d, and $d\,a$ and $d\,c$ be drawn parallel to the strings $a\,b$ and $b\,c$, a parallelogram will be formed whose adjacent sides $a\,b$ and $b\,c$ and whose diagonal $b\,d$ will have the respective values 8, 10, and 14. The point b is acted upon by three forces, represented by the respective sides of the triangle $a\,d\,b$ in quantity and direction, the weight 8 acting in the direction $b\,c$, the weight 10 acting in the direction $b\,a$, and the weight 14 acting in the direction $d\,b$.

The resultant of a number of forces acting upon the same point of a body may be determined by finding the resultant of the first two, and of this with the third, etc. This will be obvious by supposing four equal forces, $a\,e$, $b\,e$, $c\,e$, and $d\,e$, Fig. 3985, acting at right angles to each other upon the point e. The resultant of $a\,e$ and $b\,e$ will be the diagonal $f\,e$ of the parallelogram $a\,e\,b\,f$; the resultant of $f\,e$ and $c\,e$ will be $b\,e$; and that of $b\,e$ and $d\,e$ will be zero; which will also appear by observing that the forces $a\,e$ and $c\,e$ balance each other, as also do the forces $b\,e$ and $d\,e$. The resultant of any number of forces may also be found by connecting the lines representing the forces, as shown in Fig. 3986. Suppose the forces to be represented in quantity and direction by the lines $a\,b$, $b\,c$, $c\,d$, and $d\,e$. Connect the points a and e, and the line $a\,e$ will rep-

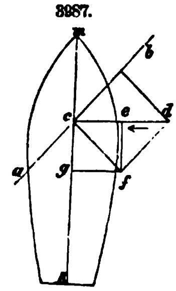
3985.



3986.



3987.

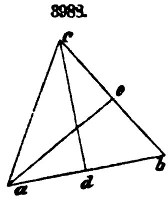


resent the resultant of all the forces in quantity and direction; for $a\,c$ is the resultant of $a\,b$ and $b\,c$, $a\,d$ that of $a\,c$ and $c\,d$, and $a\,e$ that of $a\,d$ and $d\,e$.

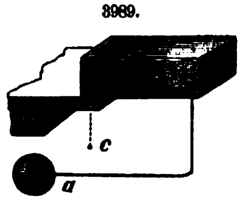
The force which impels a sail-vessel, moving with the wind off the quarter, is the resultant produced by the oblique action of the wind against the sails. Let $a\,b$, Fig. 3987, represent the position of the sail, and $d\,c$ the direction and force of the wind. This force may be resolved into the components $d\,f$ and $f\,c$, the former parallel with and the latter perpendicular to the surface of the sail, and therefore the only force which is effective. But it is not acting in the direction of the keel, $m\,k$; therefore it must be resolved into the components $f\,g$ and $g\,c$, the latter of which will represent in quantity and direction the effective propelling force given by the wind, whose force is measured by $d\,c$.

Centre of Gravity.—The point through which the resultant of all the forces caused by attraction of gravitation of the molecules of a body passes is called the centre of gravity. This point may be within the body, or, in consequence of its form, may be beyond it. The finding of the centre of gravity is a geometrical problem, but with an irregular-shaped body it can most easily be determined experimentally by suspending it in two positions, and finding the point of intersection of the two vertical lines which pass through the two points of suspension. This point of intersection will necessarily be the centre of gravity; for it is evident that it must reside in each of the two verticals, as each

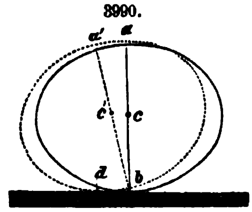
3988.



3989.



3990.



vertical is the resultant of all the gravitating forces of the body while suspended in any one position. In the case of bodies of uniform density and of geometrical form, the centre of gravity is readily determined by geometrical principles. In a circle or sphere it coincides with the geometrical centre. In a plane triangle it is at the point of intersection of two lines joining the vertices of two angles with the

middle of the opposite sides, as shown in Fig. 3988. In a cone or pyramid it is in the line joining the vertex with the centre of gravity of the base, and at one-fourth the distance from the base.

A body is said to be in equilibrium when the centre of gravity and the point of support are in the same vertical line. When the point of support is above the centre of gravity, the equilibrium is said to be stable. Founded upon this is the sometimes so-called paradox of maintaining a beam in a horizontal position with only one end resting upon a support, as shown in Fig. 3989. The condition is easily understood if the beam b and the leaden ball a, with the attached bent rod, are considered as forming one body whose centre of gravity is at c. When this is vertically below the point of support, the system will be in stable equilibrium. When a body has its centre of gravity above the point of support, but in the same vertical, it is said to be in unstable equilibrium.

A distinction must be made between a state of stable equilibrium and a merely stable condition; for equilibrium implies a balance of force. A block, for example, may rest in a stable condition when lying upon the floor, although supported below its centre of gravity. But it cannot be said to be supported by a point; if it were, this point would need to be in a vertical with the centre of gravity. There are some cases of stable equilibrium when the centre of gravity is above the point of support. Thus when the body is an oblate spheroid, stable equilibrium will exist when it rests upon one of its poles a or b, Fig. 3990, because the centre of gravity occupies the lowest possible position. Disturbing the spheroid so as to bring the axis out of the perpendicular will raise the centre of gravity, and although it carries it to one side, as from c to c', the point of support is removed still farther in the same direction, as from b to d; and therefore gravity will bring the body back till the axis is vertical.

When the point of support and the centre of gravity coincide, as in a wheel, the equilibrium is said to be indifferent, as is also the case when a sphere rests upon a horizontal plane, because the centre of gravity and the point of support will always be in a vertical line. A prolate spheroid or an egg, lying on its side upon a plane, is in a state of stable equilibrium in one direction, and in that of indifferent equilibrium in another. Supported at the pole, the case becomes one of unstable equilibrium.

The vertical line which passes through the centre of gravity is called the line of direction of the centre of gravity. A body will rest upon a horizontal plane only when the line of direction falls within the base on which it rests; and its degree of stability or power to resist change of position

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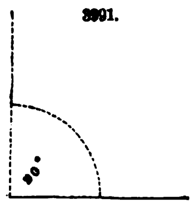

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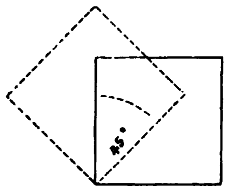

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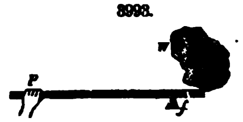
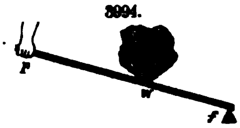
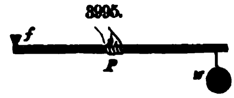


3994.



3995.



depends upon the horizontal distance of the line of direction from the edge of the base as compared with the height of the centre of gravity above the base, or upon the length of the arc which the centre of gravity will describe when the body is raised from a horizontal position of the base to that in which the line of direction falls through the edge of the base. Thus, if a horizontal plane is rotated on one edge till its centre of gravity falls in the line of direction, it will describe the quadrant of a circle, as shown in Fig. 3991; while the centre of gravity of a cube requires to be moved only through an arc of 45° in order to bring it vertically over one edge, as shown in Fig. 3992.

Mechanical Elements.—The combinations of mechanism are numberless; but the primary elements are only two, namely, the *lever* and the *inclined plane*. By the lever power is transmitted by circular or angular action—that is to say, by action about an axis; by the inclined plane it is transmitted by rectilineal action. The principle of the lever is the basis of the *pulley* and the *wheel and axle*; that of the inclined plane is the basis of the *wedge* and the *screw*.

The Lever.—The elementary lever is an inflexible straight bar, turning on an axis or fixed point called the fulcrum; the force being transmitted by angular motion about the fulcrum from the point where the power is applied to the point where the weight is raised, or other resistance overcome. There are three varieties of lever, according as the fulcrum, the weight, or the power is placed between the other two; but the action is in every case reducible to that of the three parallel forces in equilibrium. In a lever of the first kind, Fig. 3993, the fulcrum is between the power and the weight; in a lever of the second kind, Fig. 3994, the weight is between the fulcrum and the power; and in a lever of the third kind, Fig. 3995, the power is between the weight and the fulcrum. The general rule for ascertaining the relation of power to weight in the lever, whether it be straight or curved, is: The power multiplied by its distance from the fulcrum is equal to the weight multiplied by its distance from the fulcrum. Or, representing the power by P, and by p its distance from the fulcrum, and the weight by W, and by w its distance from the fulcrum, we have:

$$P : W :: w : p; \text{ or } Pp = Ww.$$

From this the following rules may be deduced:

1. To find the power: Multiply the weight by its distance from the fulcrum, and divide by the distance of the power from the fulcrum; or $P = \frac{Ww}{p}$.

2. To find the weight: Multiply the power by its distance from the fulcrum, and divide by the distance of the weight from the fulcrum; or $W = \frac{Pp}{w}$.

3. To find the distance of the power from the fulcrum: Multiply the weight by its distance from the fulcrum, and divide by the power; or $p = \frac{Ww}{P}$.

4. To find the distance of the weight from the fulcrum: Multiply the power by its distance from the fulcrum, and divide by the weight; or $w = \frac{Pp}{W}$.

If the weight of the lever be included in such calculations, its influence is the same as if its whole weight or its mass were collected at its centre of gravity. If several weights or powers act upon one or both ends of the lever, the condition of equilibrium is: $P \times p + P' \times p' + P'' \times p''$, etc. $= W \times w + W' \times w' + W'' \times w''$, etc. If the arms of the lever be equally bent or curved, the distances from the fulcrum must be measured upon perpendiculars drawn from the lines of direction of the weight and power to a line running horizontally through the fulcrum; and if unequally curved, measure the distances from the fulcrum upon a line running horizontally through it till it meets perpendiculars falling from the ends of the lever.

Work done with the Lever.—On the principle of the equality of movements, the power and the weight on the lever, neglecting frictional resistances, are to each other inversely as the length of the arms upon which they act—that is, of their radii of motion—and inversely as the arcs or spaces passed through or described by the ends of the arms. The power descending through a given arc a and the weight through an arc c, we have power $\times$ arc $a =$ weight $\times$ arc c. To show this arithmetically, let the weight be raised through 1 foot; then, with a leverage of 7 to 1, the power descends 7 ft.; and taking it at 60 lbs., the weight it raises will be 60 lbs. $\times$ 7 = 420 lbs.; and the equation of work is 60 lbs. $\times$ 7 ft., or 420 foot-pounds = 420 lbs. $\times$ 1 foot, or 420 foot-pounds.

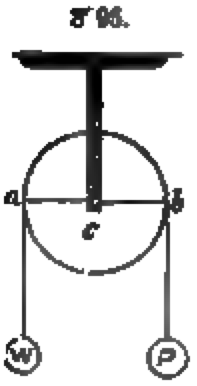
The Pulley is a wheel over which a cord or chain or band is passed in order to transmit the force applied to the cord, etc., in another direction. It is equivalent to a continuous series of levers with equal arms on one fulcrum or axis, and affords a continuous circular motion instead of the intermittent circular motion of one lever. Fig. 3996 represents a fixed pulley corresponding to a lever of the first kind. The weight W is sustained by the power P by means of a cord passed over the pulley in fixed supports, and the centre-line $a\,c\,b$ represents the element of the lever, from the ends of which the power and the weight may be conceived to depend, turning on the fulcrum c. By equality of moments, $W \times a\,c = P \times b\,c$; and the arms or radii $c\,a$ and $c\,b$ being equal, the power is equal to the weight, and the counter-pressure at the fulcrum is equal to twice the weight. The single fixed pulley simply changes the direction of the force without modifying the intensity of the power.

The pulley may be employed as a lever of the second kind by suspending the weight to the axis of the pulley, and fixing one end of the cord to a point as a fulcrum point, as shown on the left in Fig. 3997. Supposing the power to be applied at d, we shall have $P \times f\,a = W \times a\,b$. Suppose $W = 20$ and $a\,b = 1$, we have $20 \times 1 = P \times 2$, whence $P = 10$; or in other words, the leverage being as 2 to 1, the power is only half the weight. Referring again to Fig. 3996, suppose the power to be applied at c and one end of the cord to be brought to a fixed point. Then the product of the power by the radius of the pulley is equal to that of the weight by the diameter; and the leverage being as 1 to 2, the power is twice the weight. The pulley here becomes a lever of the third kind.

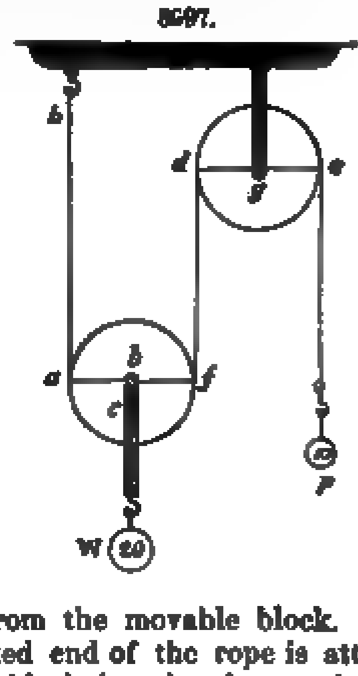
In these last two applications of the pulley, it becomes movable when in action, and by combining two or more movable pulleys on the same or different axles on one block, with one cord, the gain of power may be increased in the same proportion.

1. To find the power necessary to balance a weight or resistance by means of a system of fast and loose pulleys: Divide the weight by the number of ropes by which it is carried—that is, the number

3996.

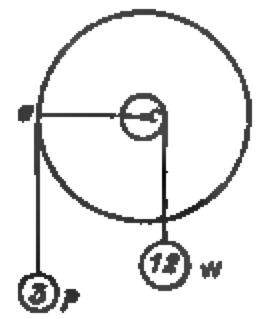


3997.



3998.

3999.



of ropes proceeding from the movable block. The quotient is the power required to balance the weight. When the fixed end of the rope is attached to the fixed block, the number of ropes proceeding from the loose block is twice the number of movable pulleys, and the power may be found

by dividing the weight by twice the number of movable pulleys. When the end of the rope is attached to the movable block, the division may be taken at twice the number of movable pulleys plus 1. Or, putting n for the number of movable pulleys, if the fixed end of the rope is attached to the fixed block, $P = \frac{W}{2n}$; and if the fixed end of the rope be attached to the movable block, $P = \frac{W}{2n+1}$.

2. To find the weight or resistance that will be balanced by a given power by means of a system of fast and loose pulleys: Multiply the power by the number of ropes proceeding from the movable block; or when the rope is attached to the fixed block, multiply the power by twice the number of movable pulleys; or when the rope is attached to the movable block, multiply the power by twice the number of movable pulleys plus 1. Thus, in the first case we have $W = 2nP$, and in the second case $W = (2n + 1)P$.

3. To find the power necessary to balance a weight by means of a system of separate movable pulleys with separate cords consecutively connected, as shown in Fig. 3998: Divide the weight by that power of 2 of which the index is the number of movable pulleys; or subdivide the weight successively by 2 as many times as there are movable pulleys to find the power required. Thus, $P = \frac{W}{2^n}$.

4. To find the weight that can be balanced by a given power by means of a system of separate movable pulleys as above described: Multiply the power by that power of 2 of which the index is the number of movable pulleys; or multiply the power successively by 2 as many times as there are pulleys. Thus, $W = P \times 2^n$.

It is necessary that the cords should be parallel to each other, as in the illustration, in order that rules 3 and 4 may apply.

Work done with the Pulley.—In using the single fixed pulley the power is equal to the weight, and the spaces through which they move in the same time are equal. With the movable pulley the weight is suspended at the axle, and in raising the weight 1 ft. the power at the circumference with a leverage of 2 passes through 2 ft., and is only half the weight; hence, as already shown, a weight double the power is raised half the height through which the power is applied. Conversely, when the weight is suspended at the circumference of the movable pulley and the power is applied at the axle, the leverage is one-half; the power is therefore double the weight, and moves through 1 ft. while the weight moves through 2 ft.

THE WHEEL AND AXLE may be likened to a couple of pulleys of different diameters united on one axis, of which the larger, a, Fig. 3999, is the wheel, and the smaller, c, the axle, with a common fulcrum in the axis, the centre-line $a\,c$ representing the elements of a lever. Here the weight W on axle c is balanced by the power P on axle a; whence $Pa = Wc$, and the following rules:

1. To find the power: Multiply the weight by the radius of the axle, and divide by the radius of the wheel; or, from the above formula, $P = \frac{Wc}{a}$.

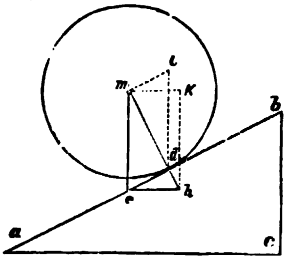
2. To find the weight: Multiply the power by the radius of the wheel, and divide by the radius of the axle; or $W = \frac{Pa}{c}$.

3. To find the radius of the wheel: Multiply the weight by the radius of the axle, and divide by the power; or $a = \frac{Wc}{P}$.

4. To find the radius of the axle: Multiply the power by the radius of the wheel, and divide by the weight; or $c = \frac{Wa}{P}$.

Work done with the Wheel and Axle.—While the wheel in Fig. 3999 makes one revolution, the axle also makes one. The power descends or traverses a space equal to the circumference of the wheel $= 2a \times 3.1416$, while the weight is raised through a space equal to the circumference of the axle $= 2c \times 3.1416$. If the radius of the wheel be 1 ft. 6 in., and that of the axle 3 in., the circumferences are 9.42 ft. and 1.57 ft., being as 6 to 1; and the power and the weight, conversely, are as 1 to 6. If the power be 20 lbs., then (P) 20 lbs. × 9.42 ft., or 188.4 foot-pounds = (W) 120 lbs. × 1.57, or 188.4 foot-pounds.

4000.



THE INCLINED PLANE is a slope, or a flat surface inclined to the horizon, on which weights may be raised. By such substitution of a sloping path for a direct vertical line of ascent, a given weight can be raised by a power which is less than the weight itself. The power is determined in the following manner: We will suppose two cases, the first in which the power is applied in a direction parallel to the plane, and the second in which it is applied in a horizontal direction, or parallel to the base. Let m, Fig. 4000, be the centre of gravity of a freely-moving body resting on a plane whose length is $a\,b$, and whose height is $b\,c$. Let the perpendicular $m\,e$ fall from the centre of gravity upon the plane; also draw $m\,d$ perpendicular to the plane. Let $m\,e$ represent the force of gravity; then will $m\,d$ represent the pressure perpendicular to the plane, and $d\,e$ or $m\,l$ will represent the force in quantity and direc-

tion with which the body tends to move downward along the plane. An equal force acting in the opposite direction will therefore produce equilibrium. Since the triangle $m\,e\,d$ is similar to $a\,b\,c$, $e\,d : e\,m :: b\,c : a\,b$. Consequently, when the power is applied in a direction parallel to the plane, equilibrium will exist where $p : w ::$ height of plane : length of plane, or $p : w ::$ sin. a : rad. In the second case, where the power is applied in a direction parallel with the base, produce $m\,d$ to h, and draw $e\,h$ parallel to the base; then will $e\,h$ or $m\,k$ of the parallelogram $m\,e\,h\,k$ represent the force necessary to produce equilibrium, and $m\,h$ will represent the pressure perpendicular to the plane. But in this case $e\,h : e\,m :: b\,c : a\,c$. Therefore, power : weight :: height of plane : length of base of plane, or $p : w ::$ sin. a : cos. a.

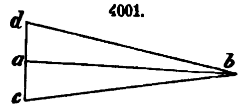
From the foregoing may be deduced the following rules:

1. To find the power: Multiply the weight by the height of the plane, and divide by the length.
2. To find the weight: Multiply the power by the length of the plane, and divide by the height.
3. To find the height: Multiply the power by the length, and divide by the weight.
4. To find the length: Multiply the weight by the height of the plane, and divide by the power.

Work done with the Inclined Plane.—The weight is raised in opposition to gravity, and the work done on it is expressed by the product of the weight into the vertical height of the inclined plane. The work done by the power is expressed by the product of the power into the length of the plane. These two products express equal quantities of work, and $P \times l = W \times h$. For example, the length of the plane is 24 ft. and the height 2 ft.; the weight is 120 lbs., and the power 10 lbs. Then the work done in raising the weight up the whole of the incline is 240 lbs.; thus, (P) 10 lbs. × 24 ft., or 240 foot-pounds = (W) 120 lbs. × 2 ft., or 240 foot-pounds. The power is here supposed to be applied in a direction parallel to the plane. If applied in a direction at an angle to the plane, it is to be resolved into its components parallel and perpendicular to the plane.

THE WEDGE is a pair of inclined planes united by their bases or "back to back," as $b\,c\,a\,d$, Fig. 4001. Whereas inclined planes are fixed, wedges are moved, and in the direction of the centre-line $a\,b$, against a resistance equally acted on by both planes of the wedge. The function of the wedge is to separate two bodies by force, or divide into two a single body. In some cases the wedge is moved by blows, as in splitting timber; in others it is moved by pressure. When pressure is applied, while the wedge and power move through a space equal to the length of the wedge $a\,b$, the weight is moved or overcome through a space equal to the breadth of the wedge $c\,d$; and as the power is to the weight inversely as the spaces described, they are to each other directly as the breadth to the length of the wedge. Hence $P \times$ length $= W \times$ breadth of wedge. Whence the following rules:

4001.

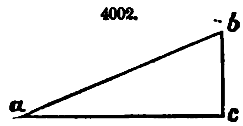


1. To find the weight of transverse resistance: Multiply the power by the length of the wedge, and divide by the breadth of the head.
2. To find the power: Multiply the weight or transverse resistance by the breadth of the head, and divide by the length of the wedge.
3. To find the length of the wedge: Multiply the weight by the breadth of the wedge, and divide by the power.
4. To find the breadth of the wedge: Multiply the power by the length of the wedge, and divide by the weight.

Work done with the Wedge.—Supposing the wedge to be driven by a constant pressure through a distance equal to its length, the work done by the power is expressed by the product of the power into the length, and the work done on the weight is expressed by the product of the weight into the breadth of the wedge. If the wedge be driven for only a part of its length, the work done by the power is in the proportion of the part of the length driven, and the work done on the weight is similarly in the proportion of the part of the breadth by which the resisting surfaces are separated.

THE SCREW is an inclined plane lapped round a cylinder. Take, for example, an inclined plane $a\,b\,c$, Fig. 4002, and bend it in circular form resting on its base. The incline may be continued, winding upward, round the same axis, and thus helical planes of any required length or height may be constructed. The helix thus made being placed upon a cylinder and the dead parts of the helix removed, the product is an ordinary screw. The inclined fillet is the thread of the screw, and is called "external." But the thread may also be applied within a hollow cylinder, and then it is "internal," as in an ordinary nut. The distance apart of two consecutive coils, measured from centre to centre, or from upper side to upper side—literally the height of the inclined plane—for one revolution, is called the pitch of the screw. The effect of a screw is estimated in terms of the pitch and the radius of the handle employed to turn either it or the nut, one on the other; and the leverage of the power is the ratio of the circumference of the circle described by the power end of the handle to the pitch. The radius is to be measured to the central point where the power is applied. The circumference being equal to the radius multiplied by twice 3.1416, or 6.28, we have $P : W :: p : r \times 6.28$, in which p is the pitch and r the radius; also, $6.28\,P\,r = N \times p$. Whence the following rules:

4002.



1. To find the power: Multiply the weight by the pitch, and divide by the radius of the handle and by 6.28; or $P = \dfrac{W\,p}{6.28\,r}$.
2. To find the weight: Multiply the power by the radius and by 6.28, and divide by the pitch; or $W = \dfrac{6.28\,P\,r}{p}$.

3. To find the pitch: Multiply the power by the radius of the handle and by 6.28, and divide by the weight; or $p = \frac{6.28\,Pr}{W}$.

4. To find the radial length of the handle: Multiply the weight by the pitch, and divide by the power and by 6.28; or $r = \frac{Wp}{6.28\,P}$.

Work done with the Screw.—In one revolution of the screw, the weight is raised through a height equal to the pitch of the thread, while the power acts through the circumference of the circle described by the point at which it is applied to a lever.

For works for reference, see MECHANICS.

STAVE MACHINERY. See BARREL-MAKING MACHINERY.

STEAM-BOILERS. See BOILERS, STEAM.

STEAM-BRAKES. See BRAKES.

STEAM-COMPRESSION OF COTTON. The object of compressing cotton-bales is to obtain the largest possible weight in stowage in a ship's hold, inasmuch as, within a certain limit, the quantity in pounds that can thus be stowed governs the price of cotton in the market through the price of freight, the latter being regulated by the amount that a ship can stow per ton register. Consequently, the result sought in compressing is the greatest possible density of material.

Bales as received from the planters vary considerably in size. Their horizontal section ranges between 8 sq. ft. (4 ft. long by 2 ft. wide) and 17 sq. ft. (6 ft. long by 34 in. wide). There would be many advantages in securing a uniform size, and the National Cotton Exchange has recommended that plantation press-boxes be equalized to give an area of cross-section of 9 sq. ft., or 54 by 24 in. The average bale may be considered as weighing 470 lbs., and it measures in volume 50 cub. ft.

The amount of compression to which this can be subjected depends upon the press used, and upon the means of securing the bale while in the press in order to prevent its undue expansion after the pressure is removed. The following figures showing degree of compression in the press and subsequent expansion were obtained by Capt. S. H. Gilman of New Orleans, by the measurement of about 1,000 bales during the cotton season of 1875–'76: Thickness of bale in press, in inches, 11.15; density per cubic foot, in pounds, 39.46; density when turned out of press, 20.90—when delivered to ship, 18.14—when stowed in ship's hold by jack-screws and mechanical means, 21.47; thickness of bales delivered on wharf, in inches, 25.35—when stowed in ship's hold, 21.42; area of horizontal section of bale, in square feet, 12.

At a trial of an India press in Liverpool, Orleans cotton was compressed to 65 lbs. per cubic foot, and tied so as to remain at 46 lbs. without injury to the staple, which opened in 30 minutes without any appearance of having been baled. All India cotton is baled to a density of 45 lbs. per cubic foot measurement on landing in England. The Champion Compress, hereafter described, in New Orleans, it is stated, has compressed a bale of good ordinary cotton to a density of 80 lbs. per cubic foot. The bale was then tied to expand to 38 lbs., and samples in a short time showed no evidence of having been pressed at all.

As regards the strength of band-iron in general use on cotton-bales, the elastic strength, according to the authority above quoted, is 2,342 lbs.; the breaking strength is 2,700 lbs.; and the stretch per lineal foot between the elastic strength and the breaking strength is about one inch.

The elastic or lifting strength of a bale of cotton compressed to 6 in. in thickness is, after having expanded 50 per cent. of its volume, 57,222 lbs. It appears from this that such a bale cannot be held with the usual six iron bands, whose total elastic strength is but 14,052 lbs., at a size approxiting nearer than 6 in. to that which it had in the press, except in cases of very large single or double bales. This deduction coincides with the results of compressing cotton in India, where the staple comes from the planter in loose bags or sacks. It is weighed in quantities of 390 lbs. at a time into a cast-iron box 18 by 48 in. in horizontal area, and is there compressed to a thickness of 12 in. and to a density of 65 lbs. per cubic foot. To hold it, 18 iron bands 1¼ in. wide (equal to 24 American bands) are applied and riveted together. The bale when removed from the press expands to about 18 in. in thickness, and to a density of about 45 lbs. per cubic foot, as already stated. Cotton compressed in this manner can be stowed in ships at the rate of 2,800 lbs. per registered ton. Twelve ships loaded in New Orleans in the spring of 1876 carried 1,424 lbs. per registered ton. A large gain in stowage is obtained by compressing two bales into one package. Details of this operation are given in connection with the description of the Champion Compress, from which it appears that a stowage of 2,545 lbs. per ton was obtained, which could have been increased to 2,870 lbs.

The apparatus used for compressing bales may be divided into two classes: *hydrostatic presses*, the power of which is constant throughout the stroke; and *progressive-lever steam-presses*, the power of which is irregularly progressive and cumulative to the end of the stroke, where the greatest pressure is exerted. The Taylor hydrostatic press, which is the principal form used in this country, is described under PRESSES, HYDRAULIC.

The form of steam-press upon which modern apparatus of the kind is based was devised by Mr. Philos B. Tyler in 1845. Its construction, as originally made, is shown in Figs. 4003 and 4004. Interposed between the piston-rod and follower of the press are levers, so arranged that at the commencement of the operation, when the resistance presented by the bale is at its minimum, the arms in connection with the follower shall be at their greatest length, while those connected with the piston shall be at their shortest. As the resistance increases, the relation of the lever-arms is changed gradually, and in proportion to the resistance of the cotton, so that at the end of the stroke just the reverse condition obtains. In Figs. 4003 and 4004, the bed *b* is inverted and attached to the under side of a beam of the frame. To the upper side of this beam is secured the steam-cylinder *a*. The

piston-rod is provided with racks which engage with the toothed sectors *c*. The sectors are connected with the follower *e* by four rods *h*. When steam is admitted to the cylinder, the piston is forced up. This causes the sectors to swing on their fulcra, and in so doing to lift up the follower over a small distance. The bale is thus forcibly compressed between the follower and the bed, and so is held until the bands are passed around it and secured.

4003.

4004.

Grader's Standard Compress, constructed similarly to the foregoing, has a second steam-cylinder placed inverted and vertically above the cylinder which rests on the bed of the machine. The upper cylinder has a shorter stroke but larger piston area than the lower one. The operation is as follows: When steam is admitted to the lower cylinder, the piston ascends, and the rack on the piston-rods vibrates the segments as already described. This motion is continued until very near the end of the stroke, when the upper extremity of the piston-rod enters a clutch, by which it becomes connected with the lower end of the piston-rod of the upper inverted cylinder. Steam is then admitted into the latter, and the pressure is by it completed, the large piston surface and short stroke affording a means of applying the very great degree of compression necessary at the end of the operation. In a machine of this description erected in New York, the lower cylinder was 48 in. in diameter, and the upper one 60 in., the strokes measuring respectively 9 and 4 ft. The floor space occupied was 14 by 18 ft., and the weight of the machine was about 100 tons. (See *Scientific American*, xxix., 287.)

The Champion Compress, represented in Fig. 4005, is the invention of Capt. S. H. Gilman of New Orleans, and has achieved very remarkable results in the compression of cotton. The dimensions of a machine built in 1876, and at the present time (1879) in active use, are as follows: Area of bed-plate, 20 by 12 ft.; depth of same, 18 in.; total height to top of reversing cylinder, 36 ft. 6 in.; diameter of main cylinder, 75 in., stroke 10 ft.; diameter of reversing cylinders, 34 in., stroke 18 in.; length of lifting-rods between centres, 32 ft. 7 in.; diameter of same, 12 in; diameter of lifting-rod shafts (ingot steel), 13 in.; diameter of sector-centre shafts (ingot steel), 18 in.; radius of sectors, 70 in.; face of arched teeth, 20 in.; pitch of same, 8 in.; stroke of lower platen, 66 in.; stroke of wedge, 12 in.; smallest space for bale, 5 in.; largest space for bale, 6 ft.; size of each of four rubber bumpers, 6 by 24 by 15 in.; length of sector-bearings, 9 in.; length of their vibration in their boxes, in degrees of their circumference, 97°; diameter of bearings, 18 in.; length of bearings of the lifting-rods at each end, 13 in.; diameter of same, 13 in.; vibration of same on circumference of upper shafts, 97′; vibration of lower ends of lifting-rods on their shafts, 4° 27′; diameter of upper tie-rods, 8 in.; of lower tie-rods, 6 in. The shafts of the lifting-rods and sector-centre shafts are all of ingot steel, turned one-eighth smaller than their boxes, which are made of brass composition 6 to 1, and those in the ends of the rods are solid rings, 1 in. thick, forced hard into the rods. The average working load on each of these bearings is 300,000 lbs. net. They are lubricated with castor-oil, and, after compressing 24,000 bales of cotton, and making not less than 40,000 compressions, are reported to show no appearance of abrasion or wear. The load on each of these bearings has

frequently been carried up to 900,000 lbs., and occasionally to 1,000,000 lbs. It must be observed, however, that this great pressure is on only about one-fourth of the time, and that it is in motion only about 5 in 60 seconds. The result indicates that the pressure of shaft-bearing can safely be carried up to 8,000 lbs. per square inch, with very slow movement, when the parts are made of such materials as are here used. The press represented in Fig. 4005 was constructed to carry a net load of 4,500,000 lbs. The factors for safety are stated not in any part to exceed 10,000 lbs. tensile for wrought iron and steel; 200 lbs. transverse and 5,000 lbs. compression for cast iron.

The valve-gear consists of one double steam-valve 7 in. in diameter, and two exhaust-valves of same make and size, all raised by cams on a rock-shaft worked by the pressman. The first exhaust-valve opens to a distributing steam-chest, with three outlets, all closed by check-valves, and leading respectively to the reversing cylinders, to the steam-jacket, and to the heater. When these are all filled with steam, at about equal pressure with the cylinder, the check-valves all drop and the other exhaust-valve opens to the atmosphere, letting the press down; and when the reversing cylinders have made their stroke forward, an escape-pipe opens behind their pistons to the atmosphere; they are pushed back again by the sectors when the press goes up. The pressure obtained in this way by the exhaust-steam into the reversing cylinders, cylinder-jacket, and water-heater, is nearly half that of the main cylinder, as is shown by the instrument. The boiler-heater constructed for this application is reported to heat the feed-water to a mean of 260°. The heater being between the pump and boilers, the pump throws cold water through the coils in the heater to the boilers. The main cylinder has a cast steam-jacket, with an annular space between it and the cylinder of 1¼ in., in which a pressure of 50 lbs. is kept up by the escape-steam as described. The boilers used for this press are three, each 35 ft. long, 48 in. in diameter, with two 16-inch flues, all made of three-eighths iron; outer shells double-riveted in all horizontal seams. They are entirely inclosed in the gaseous products of the combustion, which pass from the furnace under the shells, return to the front through the flues, and back again on the top of the shells to the chimney. The consumption of fuel when constantly running is 13 lbs. of coal per bale of cotton compressed.

The most novel features in the dynamics of this press are, its reversing cylinders, its wedge, and its upper platen; and in its statics, the novel features are its iron frame and the way in which the whole structure is tied together as one piece. The reversing cylinders stand perpendicular to the main cylinder, above and outside of it, and immediately behind the sectors when they are up, and throw their power against the sectors to force them inward and downward when the press is to be opened. These cylinders receive the exhaust-steam from the main cylinders as before described; the mean pressure as indicated by the gauge is 40 lbs. per square inch, which gives a pressure against sectors of 72,560 lbs., equal to 16 lbs. per square inch against the main piston; this starts the press down without delay. The wedge supports the upper platen by flanges which project horizontally from its lower edges, on which run small wheels, whose axles are attached by connections to the platen; the end thrust is held by connecting-rods to the frame, so that when the wedge moves the platen has a vertical movement corresponding to the slope of the wedge. The cylinder has a heavy jacket 2½ in. thick, which fits to the cylinder at both ends and at two central points. The jacket is heavily ribbed, and is attached to the side frames by two vertical flanges on each side. The cylinder, its jacket, and the two side frames, all being thus bolted together and to the beam, form one solid mass, further stiffened by the tie-rods at the foot of the sectors. The upper tie-rods take the thrust of the reversing cylinders, and also stop the upward movement of the sectors, on rubber bumpers at the top of the top frame and between the tie-rods.

In India the bales, being made of a uniform size and weight, are reduced to a uniform density. In the United States bales vary from 300 to 600 lbs. in weight, and from 8 to 17 ft. in area of horizontal section. It will at once be seen that the pressure required to reduce American bales to the greatest density varies very largely. This will be more fully illustrated by the following table. The cylinder-pressure on the Champion press has, it is stated, in exceptional cases been carried as high as 140 lbs. per square inch, applying a net pressure upon the bale of 4,663,642 lbs.

Table showing Data obtained from the Average Daily Work of the Champion Compress in New Orleans, June, 1877, by S. H. Gilman.

Depth of the Bale in the Press.	Weight per Cubic Foot.	Pressure per Square Foot.	Total net Pressure on Bale.	Pressure of Steam per Sq. Inch in Cylinder.	Angles of the Lifting-Rods and Sectors.		Cumulations of Leverage.	Dead Weight and Friction deducted from Initial Power of Press.
Inches.	Pounds.	Pounds.	Pounds.	Pounds.	Rods.	Sectors.		Pounds.
15.65	28.11	18,998	227,917	40	1.16°	54°	2.73	225,484
12.70	84.64	86,440	437,280	50	1.50°	61°	3	254.270
10.91	40.88	61,201	724,418	60	2.83°	68°	3.84	283.258
9.45	46.56	87,007	1,044,090	70	3.06°	73°	4.46	334 397
8.62	51.04	132,392	1,667,141	80	3.39°	75°	5.62	372.358
6.58	66.86	266,493	3,197,927	96	4.27°	85°	8.76	520,592

Tying Cotton-Bales.—Second in importance only to the reduction of the bale in the compress to the greatest possible density, is the question of checking the expansion of the bale when removed from the press. This expansion varies very greatly, being greatest in wide bales of light weight, and least in narrow bales of heavy weight. In order to maintain the bales as nearly as possible at the density to which they are reduced by the compress, it is necessary that each band should be drawn tightly around the bale and be secured by a tie that does not impair the tensile strength of the band. The following are the essential requisites of a band-tightener and tie, the absence of any one of which would be fatal to the result sought to be obtained: The band-tightener must be entirely flexible in order to adapt itself to the varying width of the bales, which causes them at times to project beyond

4005.

and at others to be several inches within the outer edge of the platens; it must apply the same and consequently an independent strain to each and every band; it must be so simple in its action as to enable any ordinary laborer to use it; and it must be capable of attaining a speed of at least 60 bales per hour. The tie must be self-locking, instantaneous in its action, securing the bands at their ultimate point of tension, and must not impair their tensile strength.

By universal custom six bands are used upon each bale, and six men are employed at a compress, say three on each side. To attain the greatest possible speed, it is therefore necessary that three bands be tied on each side. It will be readily understood that where so enormous a pressure is applied it is necessary that the bale should be placed exactly in the centre of the platens; for if placed flush with one edge of the platens the press would be subjected to an abnormal strain, that would fix the period of its breaking down at a short distance.

Figs. 4006 and 4007 represent a "steam bale-band tightener," invented by Capt. Gilman. Three of these are applied to each side of a press, and each has two perpendicular arms attached to two horizontal bars, upon which they move freely in any direction. These bars are vibrated by two steam-cylinders, by which means one bar is caused to pull up the band while the other forces down the tie. Fig. 4007 represents the puller in position, with the band inserted. Steam is applied first to the lifting or pulling-up cylinder, and then to the depressing cylinder, which pushes down the tie. Fig.

4008.

4006 represents the puller in its position after the bands have been tightened. Steam is then exhausted from both cylinders simultaneously, when the pullers let go of the bands and the operation is completed. In order to apply an equal strain to each band, the puller is furnished with a friction-cam and rack (as shown at *A*), which can be adjusted to any strain. It has been found in practice that 1,200 lbs. is the ultimate strain that can be thus applied without causing the bands to break when they sustain the expansive force of the bales upon being released from the press. This arrangement is indispensable, as it is proved by practice that the bands, when passed around the bales by hand and inserted in the pulleys, vary in length as much as 10 in. upon the same bale. *B*, Fig. 4006, represents the mechanism for holding the loose end of the band. It is gripped tightly between rollers moving upon an inclined plane of 7½°, as at that angle the wedge will neither slip nor stick. By this arrangement the bands do not slip as long as any strain is applied, and release themselves as soon as the strain is removed.

Fig. 4008 represents the "grip-tie," also the invention of Capt. Gilman. One end of the band is doubled over to form a bulb. The band when passed through the tie moves freely in one direction; but when pressed down so as to force the bulb into the tie, it forces the loose end of the band into the curved line of the tie, holding it securely without impairing its strength.

Experience has proved that by the use of an efficient bale-band tightener and self-locking tie the carrying capacity of a cotton-laden vessel is increased fully 20 per cent. The following example will

illustrate this fact. In 1878 the British steamship Whickham, of 1,124 tons net register, was loaded at New Orleans with cotton from various presses, all using a hand band-tightener. Her cargo consisted of 5,127 bales of cotton and 136 tons of oil-cake (equal in stowage room to 500 bales of cotton), making the equivalent of 5,627 bales of cotton, or 5 bales to the ton. About the same time the British steamship Enmore, of 1,122 tons net register, was loaded from the same presses, but without the use of a band-tightener. Her cargo consisted of 4,527 bales of cotton and 30 tons of oil-cake (equal to 110 bales of cotton), making a cargo equivalent to 4,637 bales of cotton, or 4.13 bales per ton.

Doubling Bales.—The natural tendency of all bodies when subjected to an expansive force is to assume a round form. This tendency is only checked by the degree of resistance offered by the material of which the body is composed. It is therefore evident that the broader the bale is in proportion to its thickness, the greater will be the expansion when it is freed from the pressure of the compress. A bale 32 in. in width and weighing about 350 lbs. is readily brought down to 5 in. in the Champion Compress. While in the press its longitudinal cross-section is a parallelogram 5 × 32 in. To raise the long side (32 in.) of this parallelogram into a parabolic curve 6 in. in height, it is only necessary to draw each of the ends of the short (5-inch) side 1 in. into the bale, or in other words to diminish the distance between them by 2 in. When therefore the pressure of the compress is removed, the figure of the cross-section of the bale soon becomes a paraboloid 30 in. in length and 16 in. in depth. When two such bales are returned to the press and tied together, the two parabolic curves that come in contact are reduced to a straight line through the centre of the package. The cross-section of the doubled bales forms a paraboloid of 17 × 31¼ in. A bale 26 in. wide and weighing about 480 lbs. is brought down to 7 in. in the press, and expands to 14 in. Two such bales when laid together in the press expand to 21 in. Of 20 bales doubled into 10 by the Champion Compress, the average weight per bale was 506¼ lbs.; average cubic contents per bale, 12 ft. 1½ in.; average weight per cubic foot, 42.22 lbs. The British steamship Kensington was loaded at New Orleans in 1878 partly with doubled bales, and carried the largest cargo per registered ton ever taken from an American port. Her net registered tonnage was 908 tons, and her cargo consisted of 4,976 bales, equal to 5.48 bales and 2,545 lbs. per ton register. Of this cargo, 2,990 bales were doubled, 1,662 were compressed by the Champion, using the tie and band-tightener above described, and 324 bales were from other presses. Tight compressing insures the delivery of cotton at the port of destination in better order, and reduces the cost of stowage. The Kensington's cargo was stowed for 40 cents per bale, the customary charge being at the time 60 cents.

The average width of bales received at the Gulf ports is about 32 in., while at the Atlantic ports it is about 25 in. It will thus be seen that, with presses of the same power and the use of the steam bale-band tightener and self-locking tie, vessels from the Atlantic ports should carry about 20 per cent. more pounds per registered ton than from the Gulf ports. This important fact may eventually induce planters to adopt a uniform size for boxes of plantation presses, as recommended by the National Cotton Exchange.*

STEAM-ENGINES. See Engines, Proportions of Parts of; Engines, Steam—Hoisting, Marine, Portable and Semi-Portable, Stationary (Reciprocating and Rotary), and Unusual Forms of.

STEAM-HAMMER. See Hammers, Steam, Direct-Acting.

STEAM-HEATING. See Heating by Steam and Hot Water.

STEAM-PUMP. See Pumps, Steam.

STEAM-TRAP. See Heating by Steam and Hot Water.

STEEL. Modern steels have, by reason of their new compositions and characters, so far outgrown the old definitions of iron and its compounds, that scientific societies, and even governments, have endeavored to established a new and suitable nomenclature. In another part of this article, when we have examined these new characters and their causes, we can more satisfactorily consider the terminology.

I. The Adaptation of Iron to the Useful Arts.—Iron in a pure state would be too soft and weak for most purposes of the arts. At the same time too much impurity impairs its useful qualities. Very small amounts of those impurities which necessarily associate themselves with iron during its manufacture largely change its physical character: for instance, adding 1 per cent. of carbon to soft wrought iron or steel will double its tenacity, and one-half per cent. of phosphorus will make the product too brittle for most uses. Thus the first problem in the adaptation of iron to the useful arts is to regulate its impurities, or rather its strength-giving ingredients. Iron ore must first be freed from its chemically mixed oxygen. This is done by subjecting it at a red heat to carbonic oxide; the mechanically mixed earths may afterward be expelled by compression at a welding heat, or by fusion. The "direct process" operates on this principle, but not yet in a large way with commercial success. Therefore the blast-furnace (see Furnaces, Blast) must be the starting-point. The blast-furnace also removes oxygen; but in order that the iron shall be got with rapidity and slight loss, and in order that the mechanically mixed impurities may be removed from it by difference of gravity, the whole product must be fused. To be fused at a practicable heat, the iron must have 3 to 5 per cent. of carbon; this it gets from the fuel. But at this temperature it takes up also phosphorus and sulphur if these are present; and the ores of other metals which are mixed with the iron ore are also more or less smelted, thus giving the iron almost always 1 to 3 per cent. of silicon, also manganese, chromium, etc., in varying quantities.

So far in our inquiry the problem of regulating impurities is but partly solved. The blast-furnace makes a product—cast iron—which is of great value, because it can be easily melted and run into moulds; but the blast-furnace also provides the carbon and silicon which weaken the iron, and make it unmalleable, and unfitted for tools, boilers, bridges, rails, and many constructive uses. The next

* The foregoing details concerning the Champion Compress, band-tightener, and tie have been contributed by John B. Lafitte, Esq., President of the Louisiana Cotton Tie Company, of New Orleans.

step is to get out these impurities; to do this we resort again to oxygen, the original impurity. Puddling (see IRON-MAKING PROCESSES—PUDDLING) is the process heretofore almost universally employed (until we come to modern steel processes); the others are akin to it, and more costly. Puddling is removing from crude cast iron in a reverberatory furnace its carbon and silicon, down to a few hundredths of 1 per cent., by means of oxygen derived from the air passing through the fire, or usually from oxide of iron (ore) charged with the crude iron. As the iron becomes purified, it assumes a pasty condition. Phosphorus may also be largely oxidized and so removed at low temperatures. It is just beginning to be understood how much chemical affinities change with temperature. Iron will give up an impurity to the slag at one heat, and take it back at another. Puddling and kindred processes thus produce wrought iron, which is malleable, weldable, and capable of large variations in physical qualities by means of the degree of condensation to which it is subjected in rolling or hammering into merchantable shapes, and also by means of the amount of its chemical ingredients, chiefly carbon. When a large amount of carbon, say one-half to three-quarters per cent., is left in the puddled iron, it is called "puddled steel," because it will harden and temper. This product will be further mentioned.

II. THE NATURE OF STEEL.—Although we now observe the possibility of a certain control of the impurities (the body-giving ingredients) of iron, we still have not arrived at steel; we still lack the *homogeneity of physical structure* which gives high and uniform endurance under every sort of stress. The second problem is therefore not a chemical, but a structural one. Its solution is simply the fusion of the product. Wrought iron is made only at a pasty heat; its separately formed particles are not poured, but merely welded together; and although the molecules may be the same as in steel, the masses of molecules are separated by minute layers of imperfectly expelled slag. Wrought iron is therefore a bundle of iron laminæ interspersed with threads and pockets of slag—generally three-quarters to 2 per cent. in the best iron—which impair its continuity and strength. Steel, on the contrary, having been made at the temperature of fusion, flows in a fluid state into a solid crystalline mass, from which all the slag (mechanical impurities) is expelled by the superior gravity of the metal.

But homogeneity is not the only advantage which steel has over wrought iron. 1. While the value of wrought iron depends quite as much on the amount of compression it receives in manufacture as on its chemical constituents (within the usual and normal limits), the value of steel, which is already dense when first cast, is much less dependent upon condensation. 2. While wrought iron is the result of an oxidizing process which does not allow the retention in uniform quantities of easily oxidized ingredients, such as carbon and manganese, and while wrought iron is pasty when formed and cannot therefore become incorporated with subsequently added ingredients, steel, on the contrary, may during its manufacture be varied by dilution and alloying, as well as by oxidation, and various ingredients may be incorporated with its fluid mass as reagents and fluxes before its completion, or after its completion, as molecular or as mechanical constituents. 3. Steel also has the advantage of adaptation, by means of its composition, to every variety of stress. For instance, while wrought iron is well adapted to make the tension members of a bridge, and not well adapted to resist compressive strains, steel may be made equally suitable for both purposes, by simply varying its body-giving ingredients. (See the section of this article on the effect of composition upon physical qualities, page 817.)

Having thus observed that the production of steel depends (1st) on the regulation of the impurities of iron, and (2d) on fluidity during manufacture, we have to consider the two remaining questions: (3d.) How are these conditions realized in the various processes? (4th.) In what direction and degree do foreign ingredients change the physical qualities of steel?

III. STEEL-MAKING PROCESSES.—1. THE CRUCIBLE PROCESS.—This, in its older form, is peculiar in that it is not largely a process for changing the character of ingredients, but chiefly a process for promoting the homogeneity by fusion of already refined ingredients. It consists in melting in crucibles puddled iron which has been previously carburized by cementation, and casting the product into ingots. This cemented iron, or "blister steel," is made by subjecting bars packed in charcoal to a red heat for several days, according to the degree of carburization required. It was the steel of commerce previous to 1770, when Huntsman melted it in crucibles and produced what was, from a structural point of view, the first true steel. In its latest developments, the crucible process is, besides, a process of dilution; but, unlike the Bessemer and open-hearth processes, it is not one of purifying crude iron. It consists in melting irons which are more or less decarburized and desiliconized (wrought iron or low steel) with carbon, manganese, and other ingredients. Melting down highly carburized cemented steel produces a highly carburized cast steel, quite too brittle for most structural uses; hence the necessity of starting for these uses with uncarburized wrought iron. The purification of crude iron may indeed be done in the crucible, but it is so much more cheaply done by other processes that the crucible is reserved for fine steels. Here we note an important feature of the crucible process. It may start with highly refined and purified iron, while both the open-hearth and Bessemer processes start with from 20 to 100 per cent. of crude iron. These processes, not being practically able to melt decarburized iron, require an initial fluid bath of easily melted carburized or cast iron, in which to dissolve the more purified materials. But the crucible, in the concentrated heat of the furnace, may start with purified iron in an unmelted state.

The foregoing analysis of the modes of producing and purifying iron enables us to determine how the purest crucible steel may be made. The starting-point is ore as free as possible from phosphorus, sulphur, and other harmful ingredients. This, by the Catalan or some other "direct" process, is deoxidized without combining the impurities; or, if the blast-furnace is employed, the ore is deoxidized at a low temperature, by "cold blast," so as to combine but little of the impurities. The resulting cast iron is then decarburized and desiliconized in a charcoal forge fire, or it is puddled at the lowest practicable temperature, so as to oxidize as much as possible of the phosphorus and silicon.

It is practicable thus to produce a wrought iron which has but two to three hundredths of one per cent. of any ingredient except metallic iron. To this very pure material carbon and the other ingredients required may be added in the crucible. The crucible has long had another advantage over other processes for making very sound steel: the metal may be held in a highly fluid state, out of contact with air, in the crucible, an indefinite time after all chemical action has ceased, so that gas-bubbles and slag will be expelled by means of their inferior gravity; in technical phrase, the metal is "dead-melted," so that it may be cast sound. Sound casting has, however, been accomplished in another way, which will be referred to under "The Open-Hearth Process."

Having thus observed the character and requirements of the crucible process, we are prepared to consider the means by which it is practised. The crucibles (see CRUCIBLE), or "pots," hold from 50 to 80 lbs. each, and are made of clay (Stourbridge-clay pots are used in Sheffield, the chief seat of this manufacture), or, as almost always in the United States, of plumbago mixed with a little clay. They

4009.

Section on CD

4010.

have to resist the highest attainable heat (4600° F.) for many hours, and also the chemical action of oxides and fluxes; hence they endure but for 3 to 6 charges, and are consequently a large item in the cost of crucible steel. The pots are usually charged with the steel materials in a cold state, covered with a lid which at the softening heat becomes practically air-tight, and set in a furnace. The

ordinary pot-furnace, or "melting-hole," is a chamber large enough to hold 2 to 4 crucibles and the surrounding coke fire, which is urged by a powerful draught. Many, sometimes hundreds of melting-holes are set in a line, with a common ash-pit and flue, the waste heat usually being employed to generate steam in boilers. The consumption of coke is about 3 tons per ton of steel. The Siemens regenerative gas-furnace has however reduced the combustible—not coke, but cheap coal—to 1 to 1¼ ton per ton of steel, and in some cases to less than 1 ton, thus quite revolutionizing the crucible steel manufacture, as it has also revolutionized other metallurgical processes. In Figs. 4009 and 4010 (the Siemens pot-furnace), the pots are shown in a chamber, something like the old melting-hole; they are heated not by coke, but by gas burned around them. The principle and operation of the regenerative gas-furnace can be so much more clearly explained by means of the engravings illustrating the open-hearth process, that they will not be further referred to here.

Steel which is low in carbon cannot remain fluid except at a very high temperature; hence much delay or chilling exposure by agitation or otherwise in casting will cause not only excessive scrap, but unsound (because not perfectly fluid) castings. The pots must therefore be quickly lifted out of the furnace, and expertly tipped, so that the stream of fluid steel shall pour into the mould without touching or spattering against its sides. In making large castings, many pots are successively emptied into a ladle, and from this the steel flows into the mould. The stream must be unbroken, so that a great amount of labor and skill is required. Ingot moulds are made of cast iron, and will be further referred to.

It will thus be observed that the crucible steel manufacture presents the highest possibilities with regard to quality, but not with regard to cheapness. It could not have multiplied steel rails, ships, bridges, boilers, and machines, as other steel processes have done.

Until a late day much mystery has been made to surround the crucible steel manufacture in Sheffield, and at such famous works as Krupp's in Germany. But it is the simplest of processes; and it is now known that the great success of prominent manufacturers has been due, 1st, to exceeding care and skill in the selection (generally by more crude means than chemical analysis) of the materials used; 2d, to military discipline in the difficult and dangerous operation of pouring the contents of hundreds of pots in a continuous stream; 3d, to the knowledge, which has come by many trials, of how fast and how much to heat the ingots. Large ingots (say 4 ft. in diameter and 40 tons in weight) are heated a week or more before hammering; but the heat is not so rapidly applied as to burn (harmfully oxidize) the exterior.

The capacity of crucible steel works in the United States is about 50,000 tons of ingots per year.

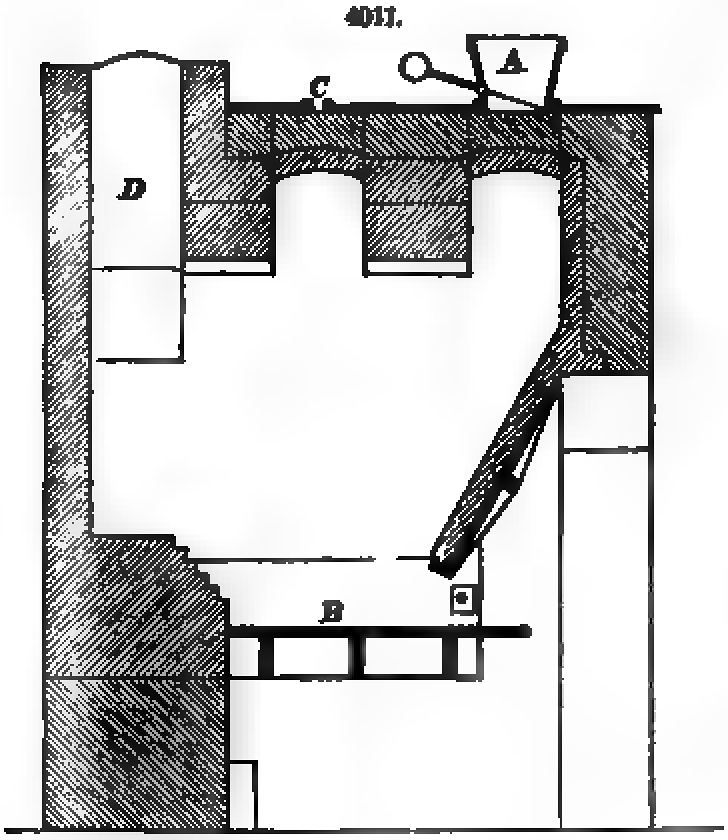
2. The Open-Hearth or Siemens-Martin Process.—The general idea of this process is the melting of steel-making materials in large quantity and cheaply, by applying flame directly to them on the hearth of a reverberatory furnace, rather than melting them a few pounds at a time by heat conducted through crucibles. In practice, however, the process has developed into, not the mere fusion of materials, but the refinement of crude materials by oxidation during fusion, and the dilution of unrefined with refined materials. It is practically necessary to start with a bath of cast iron (10 per cent. at least of the whole charge), in which the refined and hence refractory ingredients, such as wrought iron, may be easily dissolved. In order to obtain the high temperature required, an excess of air is admitted along with the gas, so as to insure complete combustion; hence the flame is oxidizing. The bath preserves the wrought iron from excessive oxidation. Although patented in its general features in 1845, by Heath, the process made little headway until other important inventions (chiefly the two first mentioned) were associated with it. 1st. The Siemens regenerative gas-furnace gives the high, uniform, and controllable heat, without which the operation could not be economically conducted. 2d. The Messrs. Martin, by applying spiegeleisen (a pig iron containing about 10 per cent. of manganese) to the melted steel, cured the red-shortness which had been an almost fatal obstacle. The action of manganese will be further considered. 3d. Dr. Siemens has more lately introduced the "ore process," by means of which a bath composed wholly of pig iron may be decarburized. 4th. Tessié du Motay and Slade have developed "phosphoric" steel, which, having more phosphorus than carbon, and also much manganese, is good for many purposes, and is cheaply made out of pig iron and old iron rails. Thus, to meet the varied requirements of cost and quality, cast iron, wrought iron in every form (such as direct-process "sponge," puddle-balls, scrap, etc.), and also steel scrap, are used in almost every proportion, with or without ore. Having thus observed the nature and range of the open-hearth process, we may better consider its apparatus and conduct in detail.

The Furnace.—In the ordinary furnace the temperature is the immediate result of combustion alone, and does not exceed about 3500° F. In the regenerative furnace the temperature may be increased above this, or up to the point of dissociation, by applying the enormous quantity of heat not used in the furnace to the fuel and to the air for its combustion. To do this successfully, the fuel must be gas. There are two systems of regeneration. The Siemens system consists in passing the heated products of combustion, as they leave the furnace, over vast surfaces of brick, upon which they deposit their heat. The entering air and gas are then passed over these hot brick surfaces, and, so to speak, wash off the heat from them and take it up themselves. Meanwhile the escaping products of combustion are heating other brick surfaces, which in their turn yield their heat to the incoming gases. The other form of regenerator is, properly speaking, a stove, in which the outgoing gases pass on one side of thin conducting partitions, while the incoming gases flow along the opposite side, the heat being continuously transmitted through the partitions.

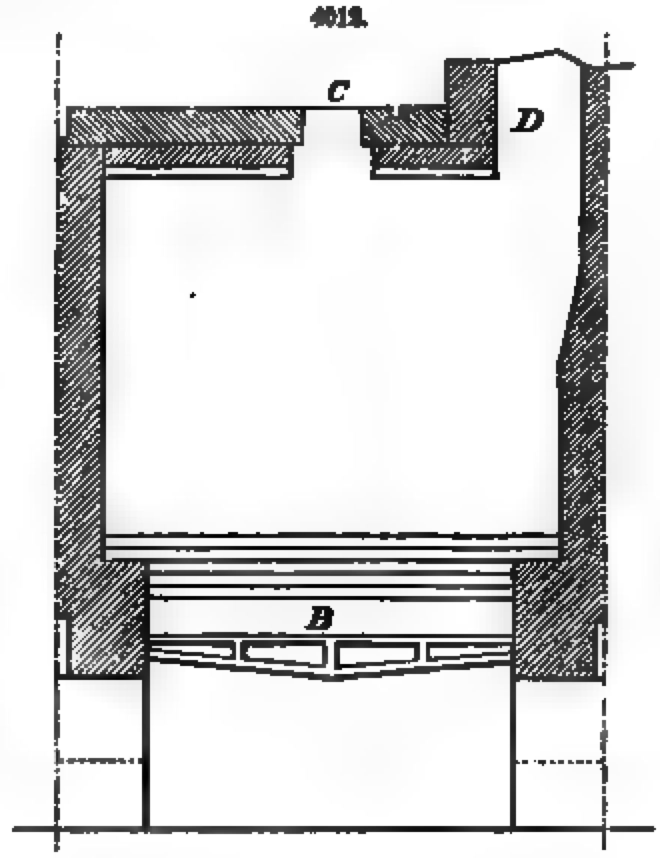
The fuel is made into gas in a vessel separate from the furnace. The ordinary form of gas-producer for bituminous coal is shown in Figs. 4011 and 4012, in longitudinal and cross section. It is a brick chamber 7 to 8 ft. square. Coal charged through the gas-tight hopper *A* is slowly burned on the grate *B*. The fire is stirred by a bar inserted at the hole *C*. By means of the flue *D* the gas enters the gas-stack, which is also the outlet of three other producers arranged around it. Thence the gas is conducted through brick or iron flues to the furnaces, which may adjoin the producers or

be hundreds of feet away. Air for combustion is usually drawn into the grate by means of the furnace-chimney, but blast is beginning to be introduced under the grates, in order to better control the rate of combustion. The coal having been lighted in the producer, the volatile constituents, chiefly hydrocarbons and water, are first evolved. Of the remaining 60 or 70 per cent. of carbon, that next the grate is burned to carbonic acid, which by rising through two or three feet thickness of incan-

4011.



4012.



descent carbon is changed to carbonic oxide. The gases passing to the furnace consist chiefly of carbonic oxide 25 per cent., hydrocarbons 10 per cent., and nitrogen 60 per cent. The producer and gas-flue should contain a slight excess of pressure over the atmosphere to prevent the inflow of air through crevices, and the consequent combustion and waste of gas. Placing the gas-producers below the furnace, or supplying them with air by a fan rather than by the furnace-chimney draught, best

4013.

accomplishes this result. Another means of producing such a plenum is the sheet-iron cooling tube, in which the gas from the stack falls toward the furnace, and is thereby cooled from 300° or 400° down to 200° or 250°, thus gaining 15 to 20 per cent. in weight, which urges it forward to the furnace.

As the regenerative furnace has become so largely used in every branch of the iron and steel manufacture, for heating as well as for melting, a somewhat extended description of it seems warranted.

The open-hearth form of it is shown in longitudinal vertical section in Fig. 4013, in cross-section in Fig. 4014, and in horizontal section in Fig. 4015. Above the floor-line (Fig. 4014) the furnace is a rectangular iron box about 22 × 10 ft. in plan, strengthened with buckstaves, roofed and lined with fire-brick, and furnished with charging-doors, like the ordinary reverberatory furnace. The sand-bed or hearth upon which the materials are melted rests in a heavy cast-iron basin, beneath which there is a free circulation of air to preserve the parts from excessive heat. By means of the spout *V* the steel is conducted to the casting-ladle. The regenerator consists of four fire-brick chambers, *K*, *L*, *M*, *N*, Fig. 4013, which are filled with a checkerwork of fire-bricks stacked loosely together, so as to present the largest amount of surface to any gas entering the chamber. From each of the end chambers *K N* two gas-ports lead up into the furnace (as shown on the right of Fig. 4013, and in plan on the right of Fig. 4015). From each chamber *L M* three air-ports lead up alongside the gas-ports to a higher point in the furnace, in order to promote a more thorough mixture of air and gas. The ports thus form a sort of vast argand burner at each end of the furnace. The gas, air, and reversing valves and flues are shown in cross-section in Fig. 4014, in plan (laid over a horizontal section of the flues) in Fig. 4015, and in longitudinal section (laid over a longitudinal section of the regenerators) in Fig. 4013. The operation is as follows: Gas from the producers, regulated by the puppet-valve *B*, passes down through the reversing valve *C* (Fig. 4013), which is so set as to throw it into the flue *F* and the regenerator *K*, where it percolates through the mass of red- to yellow-hot brickwork, and then passes at an equally high temperature into the furnace. Meanwhile, air regulated by

4014.

gas is not carefully regulated, to melt down the roof of the furnace. The flame is thrown down by the roof upon the bath of metal in the hearth; thence it passes down the ports *R S* (Fig. 4015) into the two regenerators *M N* (Fig. 4013), which absorb its heat, and thence it escapes through the flues under the two reversing valves, and into the chimney-flue *A A'*. After 20 or 30 minutes, the two left-hand regenerators having been somewhat cooled by the ingoing air and gas, and the two right-hand regenerators having been highly heated by the outgoing products of combustion, the valves *C C'* are reversed by means of the handles, when immediately the currents begin to move in the opposite direction. The gases pass into the furnace at *R S* and out through the regenerators *K L*.

The early open-hearth furnaces held but 3 tons of metal; 6 to 7 tons is a common capacity, but the newer furnaces hold 10 to 12 tons, and 16-ton furnaces are in use. Greater facility and economy so far follow increased size, and the limit seems to depend largely on the quality of the refractory materials which have to hold safely such great fluid masses at excessive temperatures. The side walls, ports, and roofs are usually built of silica-bricks, made by sticking together nearly pure silica-sand by means of 1½ per cent. of lime. A roof will last from 75 to 200 heats, according to the temperature. The furnace-bottoms are also of silica-sand, baked in layers, and are repaired after each heat by adding sand where required.

The Process.—(1.) In the "scrap process," the furnace having been highly heated, the pig iron is

charged and melted, and the scrap or uncarburized material is then added, a little at a time; sometimes the latter is preheated in an auxiliary furnace before it is charged into the bath. (2.) Or all the materials, both pig and scrap, are charged cold together; the pig melts first, and forms a bath while the rest is heating. In this method, the scrap may be somewhat more wasted by oxidation, but the oxide of iron thus formed is not lost; it operates like ore in the "ore process." This method also saves the auxiliary furnace and the rehandling of the scrap. As already indicated, the oxidizing flame purifies the crude cast iron, the silicon burning first and forming slag, the phosphorus burning slightly at this high temperature, and the carbon burning to carbonic-oxide gas, which creates a lively ebullition in the bath. (See Table II. of rate of oxidation in the ore process.)

Toward the close of the process, tests are taken. Two or three pounds of metal are dipped out and cast into a test ingot, the fracture and the toughness of which indicate to the expert very accurately the forwardness or completion of the decarburization. At the time indicated by the test, spiegeleisen or ferro-manganese is added, usually cold; it is rapidly melted and incorporated with the bath. The object of adding it is twofold. During or after the oxidation of the silicon and carbon, some iron is also oxidized. The resulting oxide of iron would render the steel unmalleable; but the manganese, having in a higher degree than anything else present an affinity for oxygen, removes it. Part of the manganese is also mechanically mixed, or molecularly incorporated, with the iron; physicists do not agree as to the method.

The exact conduct of the more common scrap process, in which part of the scrap is charged with the pig and part preheated and charged a little at a time, may best be studied from the record in Table I. of an actual typical charge. The pig and steel scrap were quite pure; the iron rails had nearly one-third of 1 per cent. of phosphorus; the resulting steel had one-quarter of 1 per cent. of phosphorus. Ferro-manganese was used in order to add as little carbon as possible to the charge. In the ordinary scrap process from 5 to 7 per cent. of spiegeleisen containing 10 to 15 per cent. of manganese is used.

Direct-Process Metal.—Excellent steel is produced from charcoal blooms made direct from the ore in the Catalan fire. The blooms are preheated and dissolved in the smallest practicable bath of crude iron. But the Catalan direct process is very expensive. Equally pure metal has been produced by other direct methods, some of which are cheap, but none of which are yet commercially developed. As the direct process is likely to be a valuable auxiliary to the open hearth, a few words may be devoted to its consideration in this connection.

(1.) Dr. Siemens's direct process consists in melting ore, together with coal and limestone enough to reduce it, in a rotating furnace, tapping off such slag as will run, squeezing the remaining slag out of the ball, and charging the ball hot into the open-hearth furnace.

(2.) Blair's process consists in deoxidizing ores rapidly by gas and solid fuel, but without fusion, and then withdrawing the sponge cold, without allowing it to oxidize again. The sponge is compressed and charged into the open-hearth bath.

(3.) Du Puy's process consists in placing the ore and carbon, together with the materials to make a

glass (for protecting the metallic iron as it is formed), in an annular sheet-iron canister, heating the canister till the ore is reduced and the slag fused, and then putting the canister and its contents into the open-hearth bath. A canister in the shape of a hollow ring is used for the purpose of holding the ore in a thin mass, so that heat will readily penetrate it, and also for the purpose of protecting the material under treatment from the gases of the furnace. The canister is, of course, a costly element.

In all these processes, the impurities of the ore are not chemically combined with the iron; they float after fusion in the bath, or, if the product is welded up into wrought iron instead of being melted, the impurities will be squeezed out in the slag.

The use of iron direct from the blast-furnace or from the cupola has not been found to facilitate the open-hearth manufacture: solid pig is purified while it is melting on the open hearth, and the purification of fluid pig appears to require as much heat and as much time.

The Ore Process.—This consists in melting down a charge of pig iron together with so much ore that the iron in the ore shall make good the waste of pig by oxidation. The oxygen of the ore is the chief agent in purifying the crude iron. A little lime is put in as a flux. Usually from 10 to 20 per cent. of steel or wrought-iron scrap is charged with the pig, because the scrap is constantly

Charge No. — TABLE I.—*Showing Conduct of Scrap Process.* July —, 1877.

DATA.	A. M.	Pig.	Steel Scrap.	Iron Scrap.	Ferro-Manganese.
	Time.	Lbs.	Lbs.	Lbs.	Lbs.
(F.) L. S. No. 2 pig .... charged at	6.20	2,582	....	....	....
(G. N.) Steel scrap .... "	6.20	...	8,170	....	....
Iron rails (M. & O.), June, 1877....... "	8.35	....	....	710	....
do. .... "	8.55	....	....	709	....
do. .... "	9.15	....	....	709	....
do. .... "	9.30	....	....	709	....
do. .... "	9.50	....	....	709	....
do. .... "	10.10	....	....	709	....
do. .... "	10.25	....	....	709	....
do. .... "	10.40	....	....	709	....
do. .... "	11.00	....	....	709	....
do. .... "	11.20	....	....	709	....
First test, nearly soft enough.	11.30	....	....	....	....
Iron rails..................................	11.45	....	....	709	....
Second test, right............................	11.55	....	....	....	....
Ferro-manganese, 63 per cent. iron............	12.08	....	....	....	75
Totals	....	2,582	8,170	7,800	75
Cast at..................................	12.15	18.65 p. c.	28.35 p. c.	57.45 p. c.	.55 p. c.

Duration.. 5 h. 55 m.
Total charge.. 13,577 lbs.
Ingots (86.9 per cent.).. 11,800 }
Scrap (9.3 per cent.)... 1,256 } 13,056 "
Waste (3.8 per cent.).. 519 "

TABLE II.—*Analyses at different Periods of the Ore Process.*

SAMPLES TAKEN—	Carbon.	Silicon.	Manganese.
	Per Cent.	Per Cent.	Per Cent.
When pig was melted...............	1.90	.57	1.140
One hour later........................	1.80	.233	.576
Two hours later......................	1.70	.188	.200
Three " "	1.65	.050	.080
Four " "	1.60	Manganese and silicon completely gone.	
Five " "	1.10		
Six " "	.60		
Seven " "	.20		

accumulating, and because it somewhat shortens the process. Pig alone can be, and often is, treated with ore. The process occupies 10 or 12 hours. For a 6-ton charge of pig and scrap, 30 cwt. of an ore containing say 60 per cent. of iron is put into the bath, a little at a time. The analyses in Table II. show the rate of oxidation of the chief impurities.

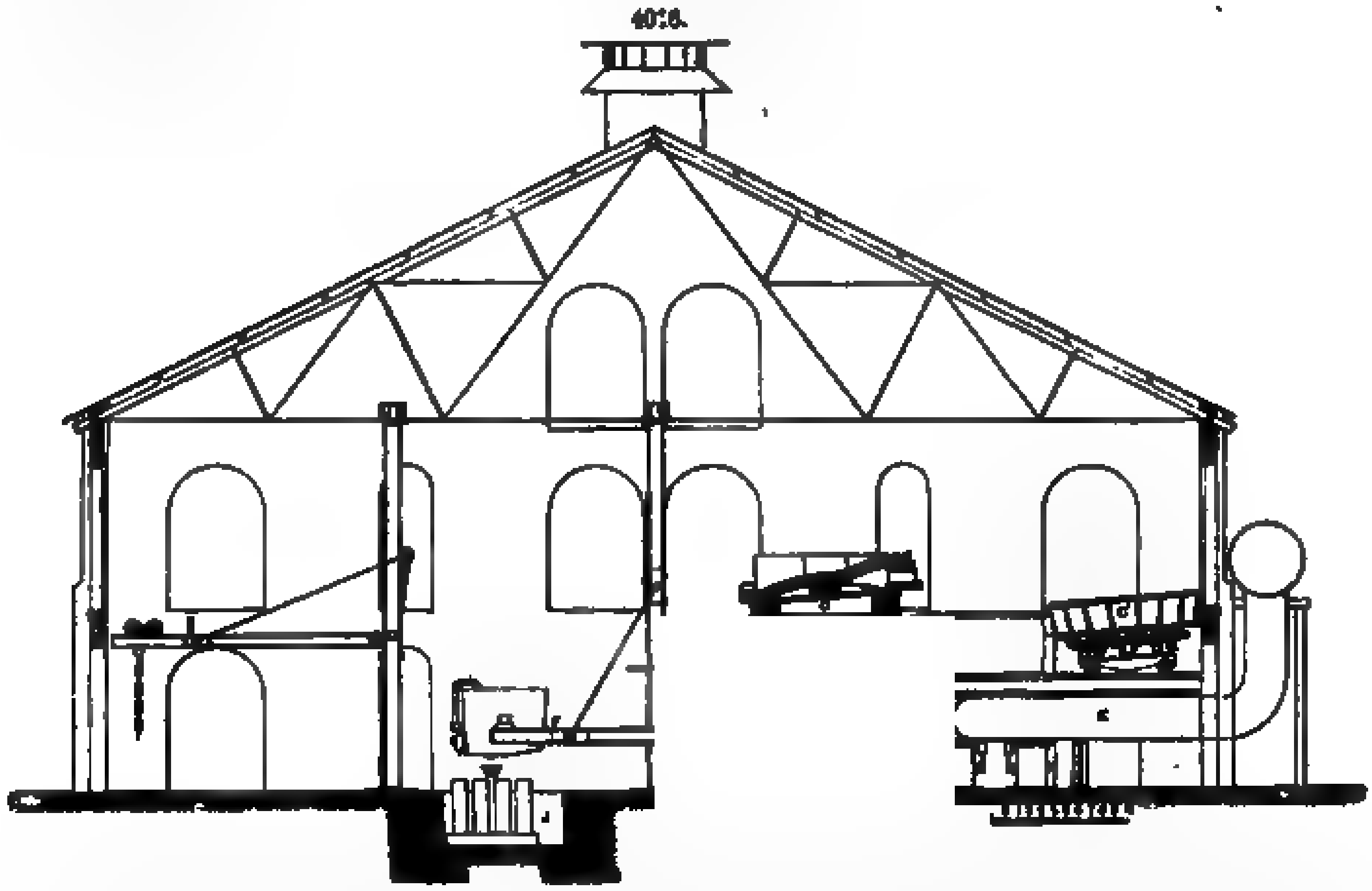
The rapid burning of the silicon forms upon the bath a slag, which, being thickened by the mechanical impurities of the ore, bubbles sluggishly, and increases in frothiness and volume. When the bath gets hotter, and carbonic oxide is rapidly eliminated from the burning carbon, the slag gets more fluid and dense, and commences vigorous ebullition. When this begins to cease, and the tests also show the complete oxidation of the carbon, spiegeleisen or ferro-manganese is added, according to the character and temper of the metal required. The ore process is, in fact, puddling carried on at a fluid instead of a pasty heat. It makes homogeneous steel instead of laminated wrought iron. But less phosphorus is oxidized at this high temperature than in the puddling process; therefore pig with a suitable amount of phosphorus must be used. The elimination of phosphorus by puddling at low temperature may however be utilized in the open-hearth process by dissolving puddle-balls thus made in the bath.

Ore is sometimes used in the scrap process, to facilitate decarburization. Its reactions tend to increase the temperature of the bath, but it should be previously heated, so as to take up as little heat as possible from the bath.

The Pernot Furnace.—In France, M. Pernot has for some years experimented upon, and has recently brought to a high state of efficiency, an open-hearth furnace with a revolving hearth, by means of which the mechanical agitation of the bath (due to the rotation) is made, as in the Bessemer process, to facilitate the chemical reactions. This furnace makes about 3½ heats from cold materials in 24 hours, and is very economical of fuel. The product of the stationary hearth is from 2 to 2½ heats from cold materials in 24 hours. A cross-section of the Pernot furnace in its latest form is shown at *C*, Fig. 4016. The regenerator is similar to that of Siemens, previously described. The hearth is shown as run out for convenient repairs at *C'*. A plan of the apparatus is shown in Fig. 4017, where *D* represents a steam-engine which gives the hearth, by means of gearing, a constant rotation of about 8 revolutions per minute.

Figs. 4016 and 4017 also show a recent arrangement of an open-hearth plant, which may have either rotating or stationary hearths. Fig. 4017 shows in plan a Pernot hearth *C*, with its ports *A* The spiegeleisen, or any stock that is to be preheated, is treated in the auxiliary furnace *B*, and

4016.



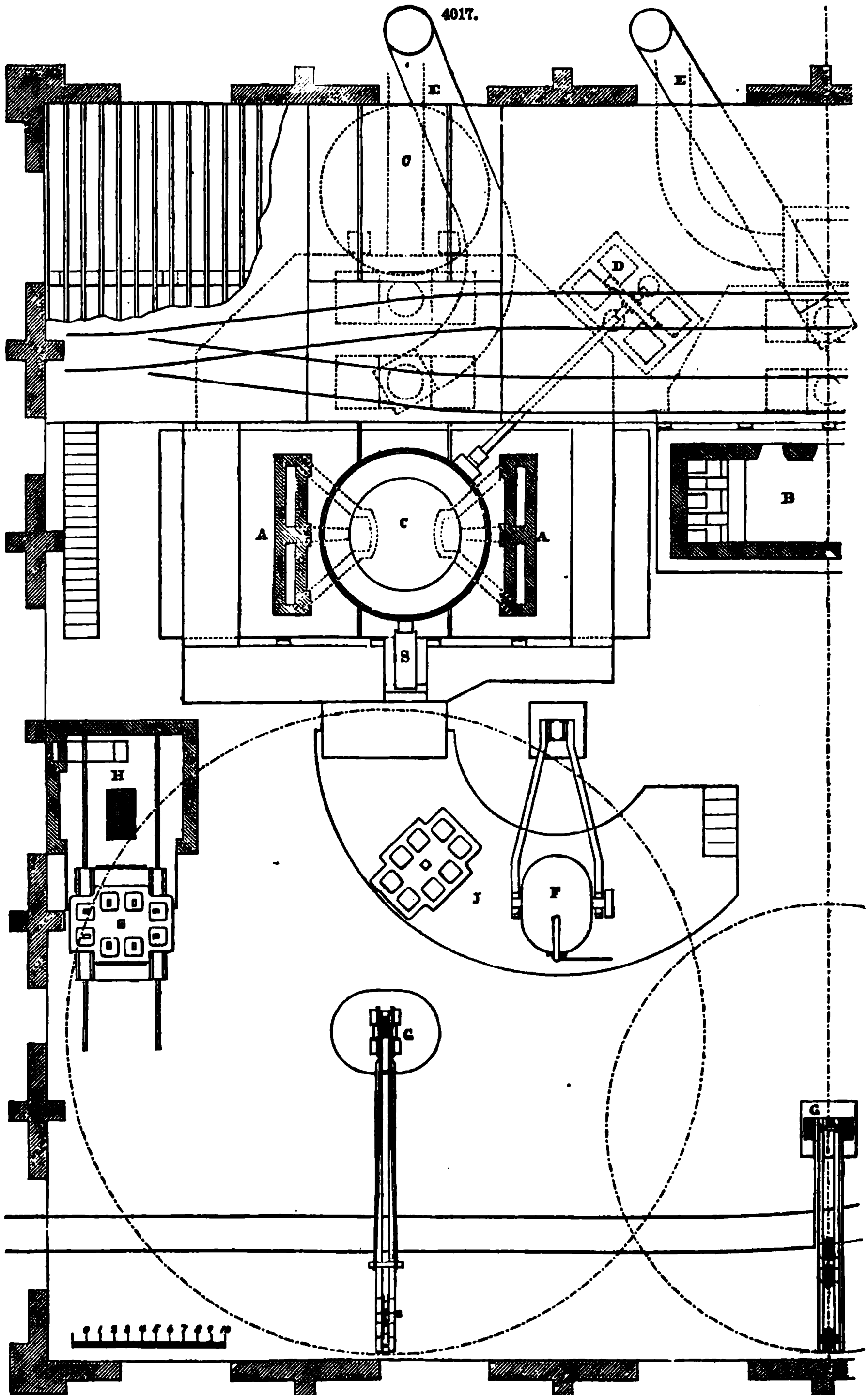
thence charged into the steel-furnace. When ready to be cast, the steel is tapped by means of the spout *S* into the ladle *F*, and thence run into the ingot-moulds, a group of which is shown at *J*. The crane *G* removes the ingots and replaces the moulds in the casting pit. *H* is an oven for heating the distributing apparatus, upon which a group of ingot-moulds are set to be filled from the bottom. Two open-hearth furnaces are set at the right of the auxiliary *B*, Fig. 4017; then an auxiliary, and so on, as required; so that one auxiliary serves two steel-furnaces. There are also a ladle-crane and an ingot-crane for each steel-furnace.

Making Large Ingots.—While small ingots—100 lbs. or less—are usually cast in split moulds, so that they can be easily removed, a large ingot is poured into a solid cast-iron mould; its shrinkage is so great that it easily slips out of the end of a mould which has a slight taper. Ingots up to 40 or 50 tons weight, containing the metal of half a dozen open-hearth furnaces or Bessemer converters, are cast by means of an intermediate ladle holding 20 or 30 tons, which sits over the mould, and also a system of steam or hydraulic cranes and of ladles moved about on wheels. The contents of two or three furnaces having been put by the smaller ladles and the cranes into the intermediate ladle, the latter is tapped by means of a fire-brick nozzle and stopper in its bottom. While the steel is running out of it, the contents of the remaining steel-furnaces are poured into it. All this is easy with proper machinery and discipline. It is not done in the United States as yet, because there has been insufficient call for large products to warrant the cost of plant. The largest ingots made here are those cast from a single furnace or converter by means of the single ladle, as shown in the accompanying open-hearth and Bessemer engravings. Ingots for rails and for bars generally are in the best practice made from 1 to 2 tons weight, "bloomed" in a heavy rolling-mill, and then cut up to be rolled or hammered into smaller shapes. This treatment saves scrap and improves quality.

Steel Castings.—The Terrenoire Company, in France, have developed the manufacture of sound steel castings which have as high a specific gravity as rolled steel, as well as the strength and physical properties generally of rolled or hammered steel of equal hardness. Although steel castings are more or less successfully made elsewhere by means of manganese and silicon, the Terrenoire process is original in following a scientific order of chemical reaction of silicon and manganese, the object being to partly prevent and partly remove the causes (chiefly the reactions of oxygen) which in ordinary steel produce unsoundness and want of solidity. It would be impracticable to further describe this important manufacture within the limits of this paper.

Production.—In 1878 there were but 22 open-hearth furnaces in the United States; the largest

4017.



number in one works is 3. In Great Britain there were above 80 furnaces, one works having 24. The yearly output of a 5- to 6-ton furnace averages about 3,000 tons; a 10-ton furnace should produce twice as much.

3. **The Bessemer Process.**—The apparatus is illustrated by the following engravings, and will be more fully described. The process is the oxidation of the carbon and silicon in melted, crude cast iron, so as to make it malleable, by means of air-blasts. This definition to some extent describes puddling and the earlier processes of making malleable iron. In all these processes the air oxidizes a portion of the iron, and the oxide of iron thus formed undoubtedly oxidizes a part of the carbon and silicon. In puddling, however, the mixture of the oxidizing agent, so that it may come in contact with all parts of the iron successively, is promoted by stirring the melted iron by manual power; but so slow is the process, and so small are the masses that can be treated by a workman, that not even the heat of the combustion thus promoted, nor even the additional heat of the burning coal, can keep the iron fluid when deprived of its carbon. The purified iron is withdrawn in a plastic condition, mixed with slag. The radical and essential difference between this process and the Bessemer process is a mechanical difference, and it consists in the intense and violent stirring of the Bessemerized iron. To this alone is due the production and maintenance of a temperature, without any other fuel than the carbon and silicon contained, that keeps the metal fluid, so that it can be cast into homogeneous, malleable ingots. In puddling, the iron is agitated by the power of one man; in Bessemerizing, it is torn into spray by a 500-horse engine. In the one case, it is stirred by a single iron bar; in the other, it is pierced by innumerable bars of air, penetrating every part, and enveloping every atom of iron in an atmosphere of oxidizing material. The combustion thus takes place, not in successive sections of the mass, but throughout the whole of it at once, and in the shortest possible time; and the heat arising from such combustion has not time to escape from the mass until purification is completed.

The Bessemer process, as first performed, and as still practised to some extent with irons containing 4 to 5 per cent. of manganese, consists in blowing the iron until all the carbon is exhausted, except what is wanted in the product. This point is determined partly by spectroscopic observation of the carbon lines of the converter flame. Some slag is also taken out of the converter, cooled, and broken; its color indicates the state of the bath. Globules of metal found in the slag are also hammered; their malleability when cold is a further indication. The manganese is not all burnt out; enough remains to prevent the formation of oxide of iron in sufficient quantity to make the product red-short. The more rapid and convenient method is to blow the iron until all the carbon is exhausted; this point is obvious from the sudden dropping of the flame. This full blowing, however, produces oxide of iron, which would make the product unmalleable, and hence it must be removed by putting in manganese to take up the oxygen, just as in the open-hearth process already described. Silicon, in oxidizing, heats the charge much more than carbon does, because the products of the former remain in the converter, while those of the latter go off in gas. In order that the charges shall work uniformly, it is important to have the silicon uniform in amount. Charges may be too hot or so cold as to chill while being cast. Manganese heats the charge like silicon, but to a less degree. (See following remarks on the direct process.) Up to the invention of the Thomas and Gilchrist method of dephosphorizing ores, mentioned farther on, no phosphorus was removed by the Bessemer process. This material is possibly oxidized at the low starting temperature, but at the finishing heat the iron has the highest affinity for it, which may be readily satisfied, as the slag and iron are boiling together.

Table III. gives analyses of various kinds of "Bessemer pig," which are also suitable for the open-hearth process. Table IV. gives analyses of the metal at different periods of the Bessemer process.

Table III.—*Average Analyses of Bessemer Pig Irons.*

GRADES.	Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
Swedish	4.70	.77	.027	Trace.	4.50
Crown Point, N. Y.	4	3	.082	.08	.05
Cumberland, England	4	3	.050	.02	Trace.
Lake Superior charcoal	3.50	2	.180	.02	.40
Le Creusot, France, from African ores	4	2	.05	.04	4

Table IV.—*Chemical Changes during the Bessemer Operation.*

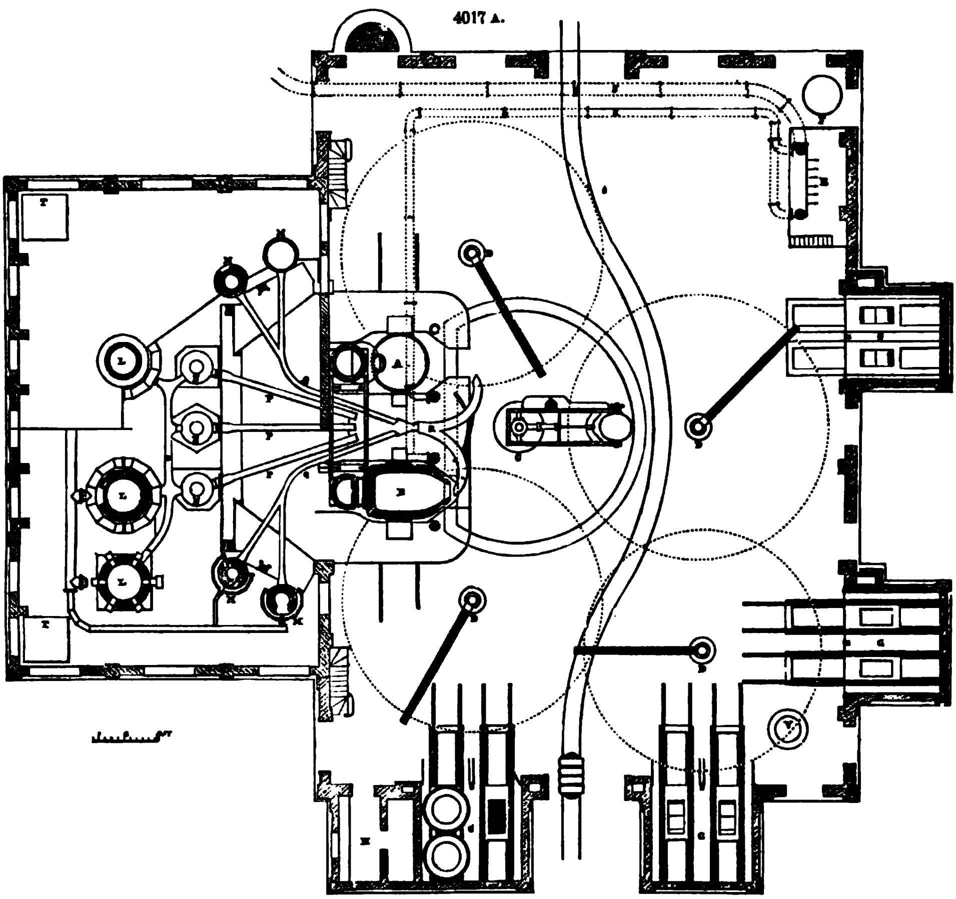
ELEMENTS.	1 (Iron).	2	3	4	5 (Steel).
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Graphite	2.07	.....	.....	....	....
Combined carbon	1.20	2.17	1.55	.097	.566
Silicon	1.952	.795	.685	.020	.080
Manganese	.086	Trace.	....	....	.809
Sulphur	.014	Trace.	....	....	....
Phosphorus	.048	.051	.064	.067	.055
Copper	.....	....	....	....	.089

No. 1. Original pig iron.
" 2. Metal and slag taken at the end of first period (6 minutes).
" 3. " " " " of the boil (12 minutes).
" 4. " " " " of the blow.
" 5. " " " after addition of spiegeleisen.

Apparatus.—Figs. 4017 A and 4018 show respectively a ground plan and a cross-section of an American Bessemer plant of the best type. The pig iron and the fuel to melt it are hoisted by hydraulic lifts *T T*, charged into one of the cupolas *L*, melted, and tapped out into one of the ladles *N*. In

case the direct process (which will be further described) is used, the ladle from the blast-furnace is hoisted up, as shown, between the cupola ladles. From the tipping-ladle the metal is poured down one of the spouts *P* and the jointed spout *R* into one of the vessels or converters *A B*. The vessel *B* is shown in section; it has a silica lining about a foot thick, and a perforated brick bottom through which the air is blown when the vessel is turned up as in Fig. 4018. The blowing engine for a pair of 7-ton vessels works up to 600 horse-power. The vessel is rotated on its trunnions by a hydraulic rack and pinion. The spiegeleisen is melted in one of the cupolas *M M*, and tapped into the vessel

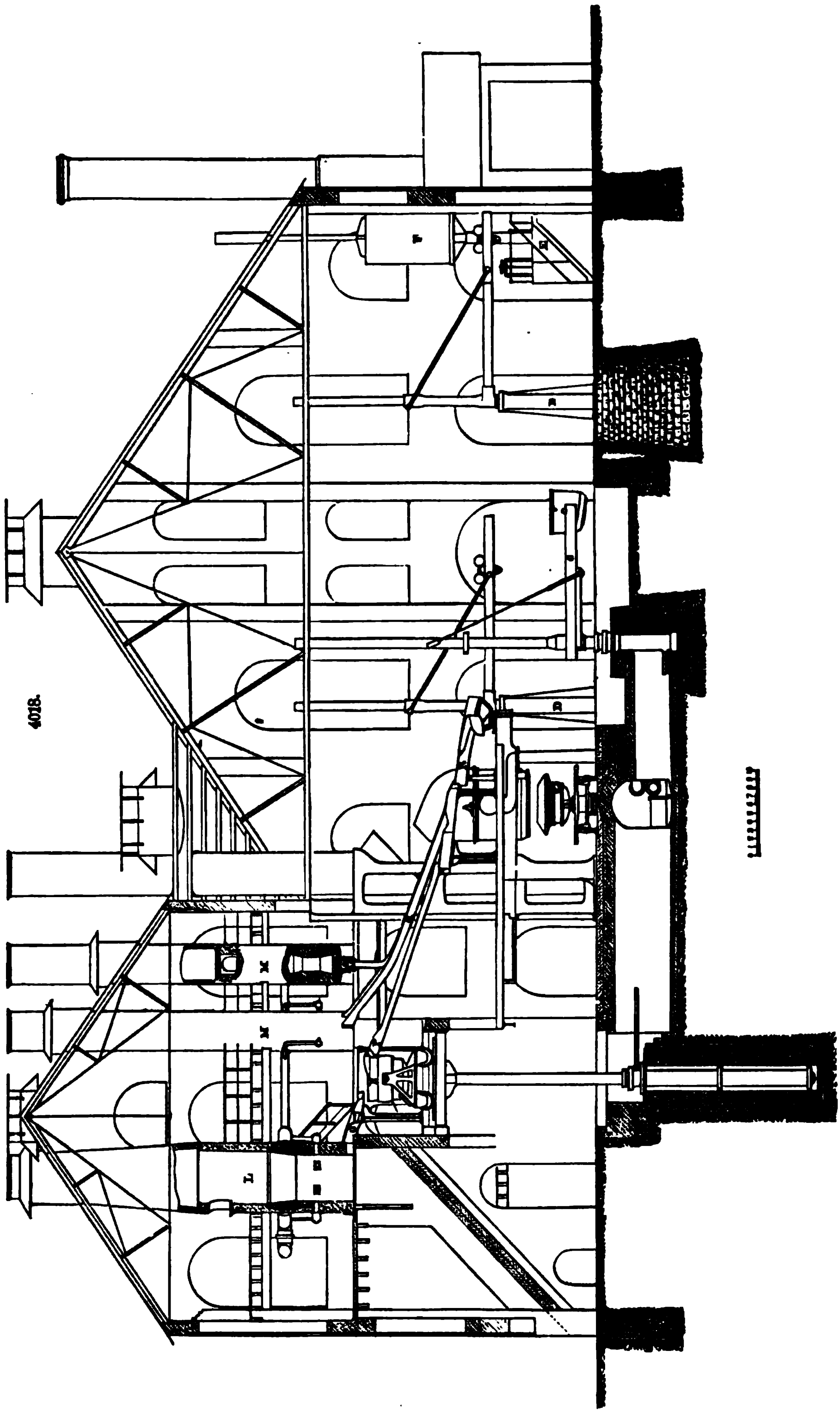
4017 A.



at the termination of the blowing. The ladle-crane *C* and the three ingot-cranes *D* are used as in the open-hearth plant. The ovens *G G* are employed to dry the vessel-bottoms and the bottom-casting apparatus. The hydraulic cranes and hoists are actuated by a pumping engine working at 300 to 400 lbs. per square inch water-pressure. The water is distributed by means of valves which are worked from the "pulpit" *E*.

Figs. 4019 and 4020 give sectional views of the converter in two positions. Fig. 4021 is a plan of the converter with the rotating machinery. The ladle into which the steel is poured from the converter is shown in Figs. 4022, 4023, and 4024. Fig. 4022 is a vertical section of the ladle-crane and elevation of the ladle. Fig. 4023 shows the platform on which the ladle moves, and Fig. 4024 is a partial section through the ladle, showing the loam-coated rod which acts as a stopper in pouring. By this latter arrangement the steel is discharged in a regulated stream, and the cinder remains on top. The steel is usually cast in ingots about 5 ft. long and 14 in. square at the base (tapering from 1 to 1½ in.), each ingot being rolled into two or three rail-blooms. When the steel is intended for other purposes than rails, moulds of special forms are used. To obviate the occurrence of air-bubbles in the steel, caused by the falling of the stream from the top to the bottom of the mould and spattering against the sides, bottom-casting is employed; that is, pouring the steel down a central sprue and causing it to enter the bottom of several moulds at a time through fire-clay distributors.

The large production of American works (which will be stated farther on) is due to the arrangement which provides large and unhampered spaces for all the principal operations of manufacture and maintenance, while it at the same time concentrates these operations. The result of concentration which is realized is the saving of rehandling, and of the spaces and machinery and cost required for rehandling; a possible result of concentration which has been avoided is the interference



4018.

of one machine and operation with another. At the same time a degree of elasticity has been introduced into the plant, partly by the duplication and partly by the interchangeableness of important appurtenances, the result being that little or no time is lost if the melting and converting operations are not quite concur-
rent, or if temporary

4021.

Cleveland and other phosphoric ores to be used commercially in the manufacture of steel, is described by the inventors, Messrs. Sidney G. Thomas, F. C. S., and Percy C. Gilchrist, F. C. S., in a paper read before the British Iron and Steel Institute in 1879. (See *Engineering*, xxvii., 377–424.) It has already been pointed out that at the conclusion of the Bessemer process whatever phosphorus there is in the iron remains there, and that it has hitherto

4022.

been found impossible in the Bessemer converter to
silicious or acid nature, and offers no means of escap
phosphoric acid in its nascent state, unless it has
relapses to its original condition, and remains comb
phide. Messrs. Thomas and Gilchrist recognized th
was an acid slag in the Bessemer converter, the remo
would be an impossibility; and they contemplated th
silicious slag of a calcareous or magnesian basic slag.
base with which the nascent phosphoric acid could co
be eliminated from the iron. This, it was seen, co
the difficulty with the lining. A ganister lining, bei
eaten away by a basic slag, and the latter would be
time; so that to render the contemplated action of th
lining also had to be provided. The inventors, afte
finally discovered that an excellent brick could be m

4023.

stone, containing from 6 to 8 per cent. of silica, 3 t
1 to 2 per cent. of oxide of iron, by firing it at ver
fire-brick-kiln temperatures being insufficient. Wi
and also in the latter, before the molten metal is ru
tity of lime in proportion to the silicon in the ir
which the influence on the slag has to be neutralized. The metal is then run in, and the blowing is continued 2½ to 3 minutes after the carbon is gone, the phosphorus meanwhile protecting the iron from oxidation. Most of the phosphorus is oxidized during this "after-blow." Spiegeleisen is then put into the converter, and the metal is run out into ingots or

castings in the usual way. It is found that for good working the slag resulting from this treatment should contain not less than 33 per cent. of lime and magnesia, while it generally contains over 40 per cent., and under 20 per cent. of silica. In contrast to this, it may be stated that the ordinary Bessemer or Siemens slag contains from 1 to 5 per cent. only of lime and magnesia, and over 40 per cent. of silica. 4084.

The Direct Process.—The direct use of blast-furnace metal in the Bessemer converter without remelting has for some years been successfully employed in France, Belgium, and elsewhere, with pretty uniform irons, containing some 5 per cent. of manganese. The oxidation of this large amount of manganese and of a small amount of silicon makes the charge hot enough to cast without an excess of scrap. At the same time, any remaining manganese becomes a useful ingredient in the steel. In fact, with such irons the blowing is in some works stopped (by means of slag-color tests above mentioned) while the charge still retains enough carbon and manganese to constitute the desired grade of steel, and no more is added. The direct use of blast-furnace metal in Great Britain, from the native and foreign ores which are best obtainable there, and which do not contain much manganese, has been practised for a shorter period, and with less marked (although substantial) success. In the absence of manganese, the necessary heat is generated only by means of an excess of silicon, and highly siliconized irons have a tendency to make a brittle product, for reasons which are not as yet perfectly understood. The direct process has but recently been tried in one American works.

Production.—There are (1879) 22 Bessemer converters of 6 to 8 tons capacity each in the United States, 2 each in 11 works. Their aggregate capacity is 900,000 tons of ingots per year. The number of converters in Great Britain, and also the number on the Continent of Europe, is much larger; but the production per vessel is considerably greater in the United States. It may be stated generally that the average output of a pair of vessels in the United States in 1876 was 225 to 250 tons of ingots per 24 hours, and that such plants are now producing about 350 tons of ingots in 24 hours. The largest output of any British works is about 200 tons out of a pair of 7-ton vessels in 24 hours. The product of the best Belgian works is about the same. In all the foreign works which make a large output, the arrangement which distinguishes the American plant has been more or less adopted.

Comparison of the Open-Hearth and Bessemer Processes.—The open-hearth process presents these favorable conditions: It allows a more complete elimination of impurities; the necessary heat is not dependent on the proportion or regularity of silicon and manganese in the pig iron; hence, and because it may use ore and old iron of inferior quality, its materials may be very cheap; at the same time, with the best materials and with the accurate means of test and control which the operation furnishes at all stages, it may produce very fine and very uniform qualities of steel, of every degree of temper and adaptation. The Bessemer process is at present the cheaper one, and the cost of plant is equally cheap per ton of product. With good and uniform irons it produces many grades of excellent steel; but facilities for tests and control are inferior, and it is less adapted to wide ranges of products.

IV. The Ingredients of Steel and their Effect on Physical Qualities.—Table V. gives the analyses of a variety of steels, from hard and excessively brittle tool-steel down to soft boiler-plate steel, which will bend double cold without fracture. The elements in many steels are quite differently grouped, but the table gives a good idea of general practice.

There are four principal hardening or body-giving elements, viz.: carbon, phosphorus, silicon, and manganese. These promote resistance to all kinds of statical strains, and they give a high resilience and elastic limit; but they impair ductility and toughness. The best results for all purposes, however, are obtained by associating some hardening element; steel could be made so pure as to impair its value. Carbon is the most effective of all the hardening elements. It not only increases tenacity and elastic limit, but it imparts the power of hardening and tempering. Suddenly cooling highly carburized steel from a red heat "combines" all the carbon, or gives it a molecular relation to the iron which promotes hardness. Heating and slowly cooling the same steel, from a red heat, brings the carbon to a graphitic state, mechanically mixed with the iron, the result being softness and increased ductility.

Table V.—*Analyses of Steel.*

Grades.	Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.	Remarks.
High tool-steel	1.00–1.25	.10–.15	.01–.02	Trace.	.10–.25	These crucible steels were all made from the same excellent wrought iron, the attempt being to vary carbon and have the other elements uniform.
Low tool-steel	.75–.80	.10–.16	.01–.02	Trace.	.17–.20	
Low machinery steel	.17–.18	.05–.06	.01–.02	Trace.	.04–.05	
Boiler-plate steel ...	.10–.11	.01–.02	.04–.05	.02–.03	.12–.20	Open-hearth, from charcoal blooms.
Rail-steel . .	.35–.40	.06–.08	.10–.12	.04–.06	.45–.65	Bessemer, from first-class pig.
Swedish plate steel.	.095	.004	.025	Trace.	Trace	Bessemer.
" gun barrel steel	.35	.058	.025	Trace.	.324	
" turning tools.	1.05	.087	.023	Trace.	.234	
Phosphoric steel...	.10–.12	.01–.05	.24–.30	.05–.09	.37–.62	Open-hearth, from 60 per cent. old iron rails made fair merchant bars.
" " .	.12–.13	.02–.04	.20–.23	.10–.18	.75–.80	Rail-steel made at Terrenoire from old iron rails. Has 70,000 to 80,000 lbs. tenacity per sq. in., and 18 to 24 p. c. elongation.
Manganese steel .	.20–.31	.05–.06	.09–.11	.05–.07	1.00–1.10	Bessemer. Has 98,000 to 112,000 lbs. tenacity and 15 to 18 per cent. elongation.
Steel castings, hard	.50–.56	.24–.29	....	...	.89–.94	Terrenoire. Projectile steel.
" " soft	.18–.20	.20–.26	..		.45–.65	" Bends double cold.

Table VI. shows the amount of carbon in various well-known irons and steels. Table VII. shows the tenacity and elongation due to various amounts of carbon, the other hardening elements being uniform and medium in amount.

TABLE VI.—*Carbon in Steels and Wrought Irons.*

Very soft puddled iron, chain-cables, armor-plates, etc.	0.01 to 0.03
Swedish bar iron	0.08 to 0.38
Iron boiler-plate	0.09 to 0.19
Iron rail (usually with one-third to one-half per cent. of phosphorus)	0.09 to 0.15
Steely iron, or puddled steel	0.30 to 0.60
Very soft Bessemer steel	0.03 to 0.04
Extra-soft Swedish Bessemer steel	0.07 to 0.08
Bessemer and open-hearth boiler-plates	0.10 to 0.20
Steel rails and tires	0.30 to 0.60
Steel for masons' tools	0.60 to 0.70
Steel for cutting tools	0.75 to 1.00
File steel	1.15 to 1.20

TABLE VII.—*Percentages of Carbon, Tenacity, and Elongation.*

CARBON.	Breaking Load, Lbs. per Square Inch.	Elongation, Per Cent.
.05 to .15	57,000 to 69,000	25 to 30
.15 to .88	69,000 to 80,000	20 to 25
.88 to .62	80,000 to 104,000	10 to 20
.62 to .88	104,000 to 126,000	5 to 10
.88 to 1.12	126,000 to 1[illegible]0,000	5

Phosphorus slightly increases tenacity and raises the elastic limit of steel; but, in a higher degree than carbon, it decreases ductility and promotes brittleness. It also impairs malleability. A large amount of reduction or compression in the manufacture from ingots to bars, improves phosphoric steel much more than it improves ordinary steel. High phosphorus and high carbon make steel very brittle. Phosphoric steels are always kept low in carbon.

Silicon is little understood. Certain experiments and practice seem to show that it does not very much affect steel, but that its oxide, silica, is the disturbing cause. The general opinion is that it has the effect of phosphorus in a lower degree.

Manganese is an important element. We have seen that its great affinity for oxygen enables it to reduce the oxide of iron which makes all steel red-short after purification by oxidation. As an ingredient in steel, it is held by most experts to promote (within certain limits) sound casting, malleability, toughness, and strengths of all kinds. Other experts believe it to be simply a mechanical and not a molecular ingredient, and hence of limited value. It is true that manganese seems to impair the quality of steel for some special uses, but on the whole it may be considered as a valuable ingredient. The makers of phosphoric steel believe that it neutralizes the mechanical effects (chiefly brittleness) of phosphorus.

Other elements affect the behavior of steel. Chromium and titanium are believed to act in some degree like manganese, but to be more effective as hardening elements. Aluminum also is recognized as a hardening element. These and other metals occur so infrequently in ordinary ores that they have not been largely studied. Chromium, titanium, and tungsten are sometimes artificially incorporated with steel.

Sulphur does not affect the useful qualities of steel structures, but it impairs the malleability of steel. When much above one-tenth per cent. is present, the steel is liable to crack in rolling and forging. The same may be said of copper, which however seems to affect welding more and malleability less. Nickel and cobalt are often present; their effect on strength is not yet traced.

It should be remarked here, that while the inexpert reader may wonder at the limited knowledge of steel-makers about the effects of these metals and metalloids, the expert reader, knowing the difficulties of arriving at this kind of conclusion, will the more wonder at the progress in chemistry and in metallurgy generally, which has given us what little clew we have got to the relations between chemical ingredients and physical qualities in iron and steel.

V. THE NOMENCLATURE OF IRON AND STEEL.—Before there were any soft steels, and the existing hard steels were used only for tools, the capacity of the material to harden by sudden cooling was very naturally its defining quality. But this capacity is not confined to cast steels; puddled iron carburized by cementation, and also incompletely puddled iron (called puddled steel), will harden equally well per unit of carbon. Cast steel, however, has an equally conspicuous quality, which is confined to it exclusively, and which puddled irons, however much carburized, do not share with it, viz.: homogeneity due to fusion. For tool-steels this is a very important quality; for structural steels it is the all-important one, while capacity to harden is of minor importance: in fact, many structural steels should have an incapacity to harden. Moreover, capacity to harden in both the cast and the puddled product is high when carbon is high; it decreases as carbon decreases, and it absolutely ceases when carbon is low, as for instance in boiler-plate steel.

Such being the facts, the late controversy about nomenclature turned on these questions: Shall the term steel be applied, as of old, to all compounds of iron that will harden, whether they are cast or puddled, and the term wrought iron be applied to those that will not harden? or shall the term steel cover all compounds of iron which have been cast from a fluid state into a malleable mass? The latter definition was, for obvious reasons, the more reasonable and convenient. But it was not deemed

sufficiently comprehensive, especially in Europe. During the Centennial Exhibition, an international committee was appointed by the American Institute of Mining Engineers to propose a better nomenclature. The following was recommended:

1. That all malleable compounds of iron with its ordinary ingredients, which are aggregated from pasty masses or from piles, or from any form of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called "wrought iron," shall be called *weld-iron* (German, *Schweisseisen*; French, *fer soudé*).

2. That such compounds when they will from any cause harden and temper, and resemble what is now called "puddled steel," shall be called *weld-steel* (German, *Schweissstahl*; French, *acier soudé*).

3. That all compounds of iron with the ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water while at a red heat, shall be called *ingot iron* (German, *Flusseisen*; French, *fer fondu*).

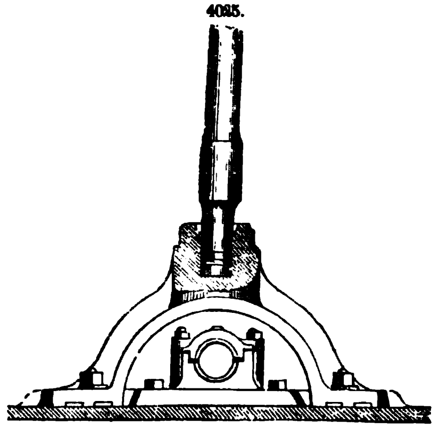
4. That all such compounds, when they will from any cause so harden, shall be called *ingot steel* (German, *Flussstahl*; French, *acier fondu*).

This nomenclature has been officially adopted in Germany, Austria, and Sweden. It is very simple, but it perhaps gives all necessary enlargement to the old terms "wrought iron" and "steel."

See works quoted under IRON-MAKING PROCESSES. A. L. H.

STEPS. Bearings for the lower ends of vertical shafts. One mode of constructing them is shown in Fig. 4025. It was at one time the practice to turn the end of the shaft hemispherical. Steps were also made, to fit which the end of the shaft was bored and a pin was inserted, or the end of the shaft was turned down so as to terminate in a sharp, hard pivot. All of these and many other devices were found more or less unserviceable, and at last millwrights began to recognize that they were increasing the pressure per square inch upon the step to an inordinate degree, and that the vertical bearing should be constructed by the same rules of proportion that govern all others. For light shafts it has been found sufficient to support the end with a vertical pillow-block carrying in its lower end a flat steel step the diameter of the shaft, while the shaft end is also shod with hardened steel and cut with cross-grooves. The ball and socket of the pillow-block insure a good bearing between the hardened surfaces, and the grooves admit sufficient oil. But in many cases the diameter of the shaft is not enough to support the weight that it has to carry without incurring too great a pressure per square inch on the step. In such an event it is best to separate the two functions of the bottom bearing, and to prevent lateral movement of the shaft by a vertical pillow-block placed immediately above the step, whose office it then becomes properly to sustain the superincumbent weight.

4025.



An excellent step for this purpose may be made as shown in Figs. 4026 and 4027. The lower end of the shaft is shaped to a square, which fits loosely into a corresponding socket in a cast-iron disk *A*, faced on its lower side, and provided with crossing grooves *E E* for oil. This disk abuts against a similar piece *B*, of square horizontal section, turned true on top and terminating below in a convex surface, rocking on the bottom of the box *C* in which the step is contained. *B* is provided with a centre-hole, met by others drilled in from its periphery, which serve to convey oil to its centre. The surrounding box *C* is filled with oil, which finds its way into the holes *D*, and is pumped up by the

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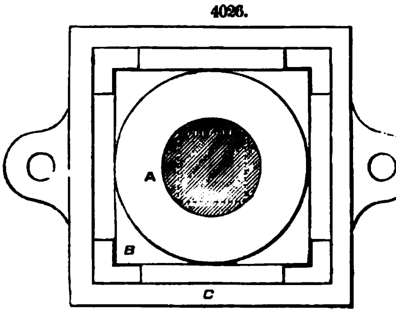

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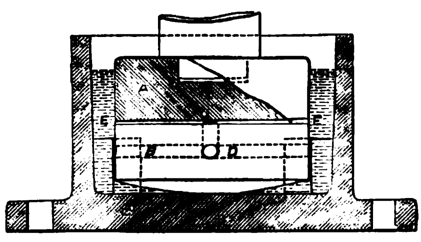


centrifugal action of the grooves *E E*, and distributed over the wearing surfaces; while the convexity of the loose piece *B* enables it to present a perfect bearing to the fixed disk *A*, and its square section prevents it from turning. If the velocity of the shaft be not excessive, and the pressure per square inch on the step be not over 50 lbs., the durability of the step will be practically endless. Under this pressure the disks never touch, but are constantly kept apart by a film of oil. Steps thus made by Messrs. William Sellers & Co. have been found, we are informed, after 25 years' constant running, still to show the tool-marks of the lathe in which the wearing surfaces were trued up.

In proportioning such a step, it is only necessary to divide the total weight to rest on it by 50, multiply by 0.854, and extract the square root of the quotient, and the result will be the diameter required.

Example.—To find diameter of step for a 4-inch shaft 30 ft. high, carrying 1,500 lbs. weight of gears and couplings: Total weight of shaft and attachments, say 2,770 lbs.; then $\frac{2770}{50 \times .7854} = 70.53$, and $\sqrt{70.53} = 8.4$ inches = diameter of step required. C. S., Jr.

STONE, ARTIFICIAL. See CONCRETES AND CEMENTS.

STONE-BREAKER. See BREAKER OR CRUSHER.

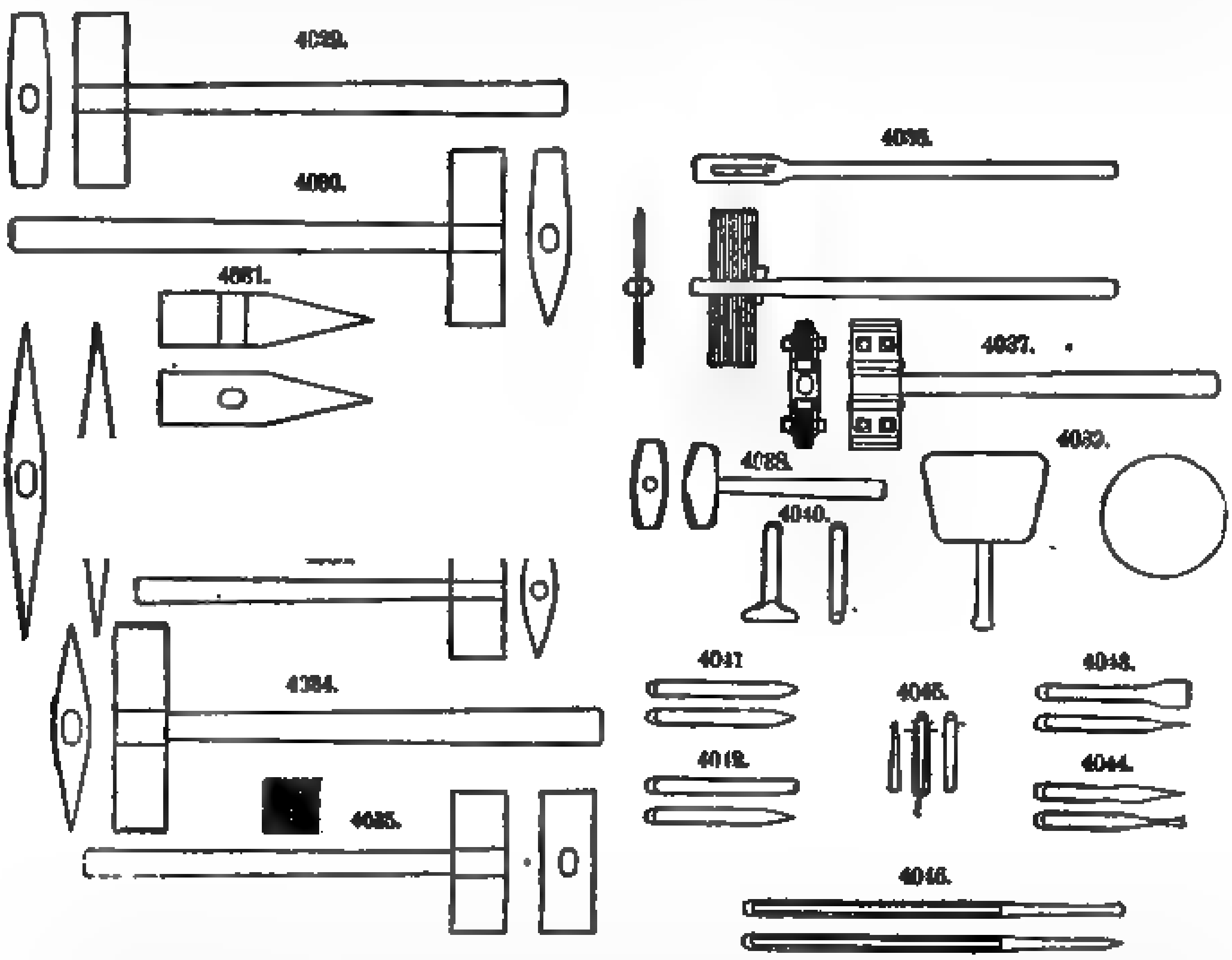
STONE-CARVING MACHINE. A machine for carving panels and mouldings on stone by means of a diamond tool. Fig. 4028 represents an apparatus of this class, which consists of an iron frame holding a table which can be raised and lowered by turning the handle seen at the upper right-hand corner, this connecting with the screw seen under the table, while the stone to be shaped is laid on top. The diamond drill is connected with a vertical axis, rapidly rotated by means of the belt seen at the top of the machine. The universal joint, by means of which connection is made with the drill to this moving axis, consists of a spiral steel band, which may be turned at a right angle to the original axis. In the engraving the drill is represented in an oblique position, cutting a groove with moulding in the surface of a stone. The whole system to which the rotating diamond drill is attached can be moved from right to left by hand, while an automatic motion may be thrown on, moving it forward and backward. The cross-bars giving it steadiness are provided with friction-rollers running at the sides, supporting guide-pieces, which are firmly attached to the uprights at the four corners of the frame. One of these is represented removed in order better to expose the arrangement of the working parts in the centre. The automatic feed, giving the forward and backward movement to the drill, is seen at the left; the pulley at the extreme end turns a long screw, the rotation of which may be reversed by the motion of a crank: the screw is situated behind two horizontal sliding bars, and works in a sliding nut attached to the drill support, which follows the motion of the sliding nut.

STONE-CUTTERS' TOOLS. (For stone-saws, see SAWS.) Formerly stone-cutters' tools were made of iron with steel edges; the modern practice is to make them wholly of steel.

The *double-face hammer*, Fig. 4029, is a heavy tool weighing from 20 to 30 lbs., used for roughly shaping stones as they come from the quarry and for knocking off projections. This is used only for the roughest work. The *face-hammer*, Fig. 4030, has one blunt and one cutting end, and is used for the same purpose as the double-face hammer, where less weight is required. The cutting end is used for roughly squaring stones preparatory to the use of finer tools. The *cavil*, Fig. 4031, has one blunt and one pyramidal or pointed end. It weighs from 15 to 20 lbs. Used in quarries for roughly shaping stone for transportation. The *pick*, Fig. 4032, somewhat resembles the pick used in digging, and is used for rough dressing, mostly on limestone and sandstone. Its length varies from 15 to 24 in., the thickness at the eye being about 2 in. The *axe* or *pene-hammer*, Fig. 4033, has two opposite cutting edges. It is used for making drafts around the arris or edge of stones, and in reducing faces and sometimes joints to a level. Its length is about 10 in. and the cutting edge about 4 in. It is used after the point and before the patent hammer. The *tooth-axe*, Fig. 4034, is like the axe, except that its cutting edges are divided into teeth, the number of which varies with the kind of work required. This tool is not used in granite and gneiss cutting. The *bush-hammer*, Fig. 4035, is a square prism of steel whose ends are cut into a number of pyramidal points. The

length of the hammer is from 4 to 8 in. and the cutting face from 2 to 4 in. square. The points vary in number and size with the work to be done. One end is sometimes made with a cutting edge like that of the axe. The *crandall*, Fig. 4036, is a malleable-iron bar about 2 ft. long, slightly flattened at one end. In this end is a slot, 3 in. long and three-eighths of an inch wide. Through this slot are passed ten doubled-headed points of quarter-inch square steel, 9 in. long, which are held in place by a key. The *patent hammer*, Fig. 4037, is a double-headed tool so formed as to hold at each end a set of wide thin chisels. The tool is in two parts, which are held together by the bolts which hold the chisels. Lateral motion is prevented by four guards on one of the pieces. The tool without the teeth is $5\frac{1}{2} \times 2\frac{3}{4} \times 1\frac{1}{2}$ in. The teeth are $2\frac{3}{4}$ in. wide. Their thickness varies from one-twelfth to one-sixth of an inch. This tool is used for giving a finish to the surface of stones.

All of the above-mentioned are two-handed, or require both hands of the workman to use them. The remaining tools to be described require the use of only one hand for each. The *hand-hammer*, Fig. 4038, weighing from 2 to 5 lbs., is used in drilling holes and in pointing and chiseling the harder rocks. The *mallet*, Fig. 4039, is used where the softer limestones and sandstones are to be cut. The



pitching chisel, Fig. 4040, is usually of $1\frac{1}{4}$-inch octagonal steel, spread on the cutting end to a rectangle of $\frac{1}{8} \times 2\frac{1}{2}$ in. It is used to make a well-defined edge to the face of a stone, a line being marked on the joint surface, to which the chisel is applied, and the portion of the stone outside of the line broken off by a blow with the hand-hammer on the head of the chisel. The *point*, Fig. 4041, is made of a round or octagonal rod of steel, from $\frac{3}{4}$ in. to 1 in. diameter. It is made about 12 in. long, with one end brought to a point. It is used until its length is reduced to about 5 in. It is employed for dressing off the irregular surface of stones, either for a permanent finish or preparatory to the use of the axe. According to the hardness of the stone, either the hand-hammer or mallet is used with it. The *chisel*, Fig. 4042, of round steel of $\frac{1}{2}$ to $\frac{7}{8}$ in. diameter and about 10 in. long, with one end brought to a cutting edge from $\frac{1}{4}$ in. to 2 in. wide, is used for cutting drafts or margins on the face of stones. The *tooth-chisel*, Fig. 4043, is the same as the chisel, except that the cutting edge is divided into teeth. It is used only on marble and sandstones. The *splitting chisel*, Fig 4044, is used chiefly on the softer stratified stones, and sometimes on fine architectural carvings in granite. The *plug*, a truncated wedge of steel, and *the feathers*, of half-round malleable iron, Fig. 4045, are used for splitting unstratified stone. A row of holes is made with the *drill*, Fig. 4046, on the line on which the fracture is to be made. In each of these holes two feathers are inserted, and the plugs lightly driven in between them. The plugs are then gradually driven home by light blows of the hand-hammer on each in succession until the stone splits.

In architectural carving, a variety of chisels of different forms are used. For most of these no specific names exist, and their shapes are varied with the special work to be done.

The foregoing article is abridged from a paper on the "Nomenclature of Building Stones and of Stone Masonry," by Messrs. Croes, Merrill, and Van Winkle, in the *Transactions of the American Society of Civil Engineers*, November, 1877.

STONE-CUTTING. (See also MASONRY and STONE-CUTTERS' TOOLS.) All stones used in building come under one of three classes, viz.: 1. Rough stones that are used as they come from the quarry;

2. Stones roughly squared and dressed; 3. Stones accurately squared and finely dressed. In practice, the line of separation between them is not very distinctly marked, but one class gradually merges into the next.

Unsquared Stones, or Rubble.—This class covers all stones which are used as they come from the quarry, without other preparation than the removal of very acute angles and excessive projections from the general figure. The term "backing" which is frequently applied to this class of stone is inappropriate, as it properly designates material used in a certain relative position in a wall, whereas stones of this kind may be used in any position.

Squared Stones.—This class covers all stones that are roughly squared and roughly dressed on beds and joints. The dressing is usually done with the face-hammer or the axe, or in soft stones with the tooth-hammer. In gneiss it may be necessary to use the point sometimes. The distinction between this class and the third lies in the degree of closeness of the joints which is demanded. Where the dressing on the joints is such that the distance between the general planes of the surfaces of adjoining stones is half an inch or more, the stones properly belong to this class. Three subdivisions of this class may be made, depending on the character of the face of the stone:

(*a.*) *Quarry-faced* stones are those whose faces are left untouched as they come from the quarry. (*b.*) *Pitched-faced* stones are those on which the arris is clearly defined by a line beyond which the rock is cut away by the pitching chisel, so as to give edges that are approximately true. (*c.*) *Drafted* stones are those on which the face is surrounded by a chisel-draft, the space inside the draft being left rough. Ordinarily, however, this is done only on stones in which the cutting of the joints is such as to exclude them from this class. In ordering stones of this class, the specifications should always state the width of the bed and end joints which are expected, and how far the surface of the face may project beyond the plane of the edge. In practice the projection varies between 1 in. and 6 in. It should also be specified whether or not the faces are to be drafted.

Cut Stones.—This class covers all squared stones with smoothly-dressed beds and joints. As a rule, all the edges of cut stones are drafted, and between the drafts the stone is smoothly dressed. The face, however, is often left rough, when the constructions are massive. In architecture there are a great many ways in which the faces of cut stone may be dressed, but the following are those that will usually be met in engineering work: (*a.*) *Rough-pointed.* When it is necessary to remove an inch or more from the face of a stone, it is done by the pick or heavy points until the projections vary from ¼ in. to 1 in. The stone is then said to be rough-pointed. This operation precedes all others in dressing limestone and granite. (*b.*) *Fine-pointed.* If a smoother finish is desired, rough-pointing is followed by fine-pointing, which is done with a fine point. It is only used where the finish made by it is to be final, and never as a preparation for final finish by another tool. (*c.*) *Crandalled.* This is only a speedy method of pointing, the effect being the same as fine-pointing, except that the dots on the stone are more regular. The variations of level are about one-eighth of an inch, and the rows are made parallel. When other rows, at right angles to the first, are introduced, the stone is said to be *cross-crandalled.* (*d.*) *Axed or pene-hammered, and patent-hammered.* These two vary only in the degree of smoothness of the surface which is produced. The number of blades in a patent hammer varies from 6 to 12 to the inch, and in precise specifications the number of cuts to the inch must be stated, such as 6-cut, 8-cut, 10-cut, 12-cut. The effect of axing is to cover the surface with chisel-marks, which are made parallel as far as practicable. Axing is a final finish. (*e.*) *Tooth-axed.* The tooth-axe is practically a number of points, and it leaves the surface of a stone in the same condition as fine-pointing. It is usually, however, only a preparation for bush-hammering, and the work is then done without regard to effect so long as the surface of the stone is sufficiently leveled. (*f.*) *Bush-hammered.* The roughnesses of a stone are pounded off by the bush-hammer, and the stone is then said to be "bushed." This kind of finish is dangerous on sandstone, as experience has proved that sandstone thus treated is very apt to scale. In dressing limestone which is to have a bush-hammered finish, the usual sequence of operations is: 1st, rough-pointing; 2d, tooth-axing; 3d, bush-hammering. (*g.*) *Rubbed.* In dressing sandstone and marble, it is very common to give the stone a plane surface at once by the use of the stone-saw. Any roughnesses left by the saw are removed by rubbing with grit or sandstone. Such stones, therefore, have no margins. They are frequently used in architecture for string-courses, lintels, door-jambs, etc.; and they are also well adapted for use in facing the walls of lock-chambers, and in other localities where a stone surface is liable to be rubbed by vessels or other moving bodies. (*h.*) *Diamond panels.* Sometimes the space between the margins is sunk immediately adjoining them, and then rises gradually until the four planes form an apex at the middle of the panel. Such panels are called diamond panels, and, in the case described, the panel is a sunk diamond panel. When the surface of the stone rises gradually from the inner lines of the margins to the middle of the panel, it is called a raised diamond panel. Both kinds of finish are common on bridge-quoins and similar work. The details of this method of dressing should be given in the specifications.

The foregoing article is abridged from a paper on the "Nomenclature of Building Stones and of Stone Masonry," by Messrs. Croes, Merrill, and Van Winkle, in the *Transactions of the American Society of Civil Engineers*, November, 1877.

STOVES AND HEATING FURNACES. Fireplaces.—In private dwellings, where changes of temperature are so frequent, it is of great advantage to keep the warming and ventilation of the several dwelling-rooms independent of each other. On this account the open fireplace has always held its own as being the most convenient. With an open fireplace, a velocity will frequently prevail in the chimney of 10 ft., and in some instances of 15 ft. per second, thus causing, with a flue 14 in. by 9 in., the removal of from 30,000 to 45,000 cub. ft. per second. But as a rule there is no provision whatever made for replacing the air thus removed. The hotter we make the fire, the more heated air do we send up the chimney, and the more cold air do we bring in to supply its place. Careful experiments have shown that with an ordinary open fireplace five-sixths of the heat passes up the chim-

ney. The way in which such a fireplace acts to create circulation of air in a room with closed doors and windows is as follows: The air is drawn along the floor toward the grate, it is then warmed by the radiating heat of the fire, and part is carried up the chimney with the smoke, while the remainder flows upward near the chimney-breast to the ceiling, and, as it cools in its progress toward the opposite wall, descends to the floor, to be again drawn toward the fireplace. It follows from this that, with an open fireplace in a room, the best position in which to deliver the fresh air required to take the place of that which has passed up the chimney is at some convenient point in the chimney-breast, between the chimney-piece and the top of the room; for the air thus falls into the upward current, and mixes with the air of the room without perceptible disturbance.

The principle of Galton's ventilating fireplace, Fig. 4047, is derived from these considerations. Fresh air is admitted at the back, where it is warmed by a large heating surface, and then carried by a flue, adjacent to the chimney-flue, to the upper part of the room, where it flows into the currents which already exist in the room. The fireplace preserves an equable temperature all over the room, and provides a large amount of fresh warmed air. Gen. Morin's experiments on this ventilating fireplace showed that, with the ordinary fireplace, the heat utilized in a room amounted only to 0.125 of the heat given off from fuel, while in Galton's ventilating fireplace the heat utilized in a room rose to 0.355 of the heat given off from the fuel. Therefore, to produce the same degree of warmth in a room, Galton's fireplace requires only one-third of the quantity of coal required by an ordinary fireplace. It may be laid down as an axiom that every fireplace should be furnished with some means of admitting fresh warmed air.

4047.

FIREPLACE HEATERS.—Fireplace heaters originated in the so-called Latrobe stove in Baltimore, Md.; and one of the earliest American

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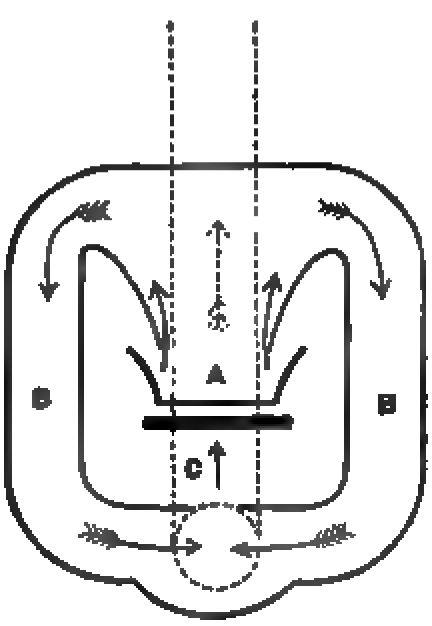

patents for this mode of warming was that granted to S. B. Sexton in 1859. In this heater there was a so-called fuel-magazine, the coal in which when the heater was in operation was entirely burning; so that the device therefore differed from the modern type of magazine heater. (See "Base-burning Stoves" in this article.) The heater was set flush with the wall, and was intended to warm the room in which it was placed as well as the apartments above. Heaters were afterward made differing from Sexton's mainly in that they protruded into the room. In 1868, or thereabouts, magazines such as are used in outstanding stoves were combined with fireplace heaters, thus rendering the latter more effective.

The essential points of a fireplace heater consist of a fuel-magazine fed from the top or upper part, a fire-pot, and a grate beneath. Space is left between the surface of the grate and the lower part of the fire-pot sufficient to admit of cleaning the fire.

The general arrangement of an improved form of heater will be understood from Fig. 4051. The circulation of the smoke from the fire-pot through the side flues *B*, and thence up the rear flue *C*, is shown in the diagram, Fig. 4048. These flues are inclosed in the air-chamber and heat the air therein, the warmed current passing up the encasing pipes as shown in Figs. 4049 and 4050. The Bristow fireplace heater, made by the Bristow Stove Company of New York, is represented in Fig. 4051, and is an example of one of the most improved forms. The construction is clear from the illustration, and the heated air follows the course indicated by the arrows.

STOVES.—Stoves in the United States are of great diversity of forms, of cast iron, sheet iron, and sometimes of soapstone. Iron stoves especially for burning coal are commonly lined with fire-brick, which not only increases their durability, but prevents the metal from being overheated. They heat

by radiation in all directions from their surface; they also heat the air, which, rising into the upper part of the room, is diffused by circulation. Where a room is tight, with no loss of heat by outflowing air, and the smoke escapes into the chimney at the temperature of the room, the stove becomes the perfection of economy in heating. The desirable points in stoves are automatic regulation of the draught, accurate fitting of the parts, inclosure of the fire-space with slow conductors, and the bringing of all the heated products of combustion in contact with the largest possible absorbing and radiating metallic surface, so that the iron will give out its warmth at a low temperature.

Base-burning Stoves are simply surface-burning stoves provided with a magazine for reserve coal, suspended from and within the centre of the upper section, and reaching to a point 4 to 6 in. above

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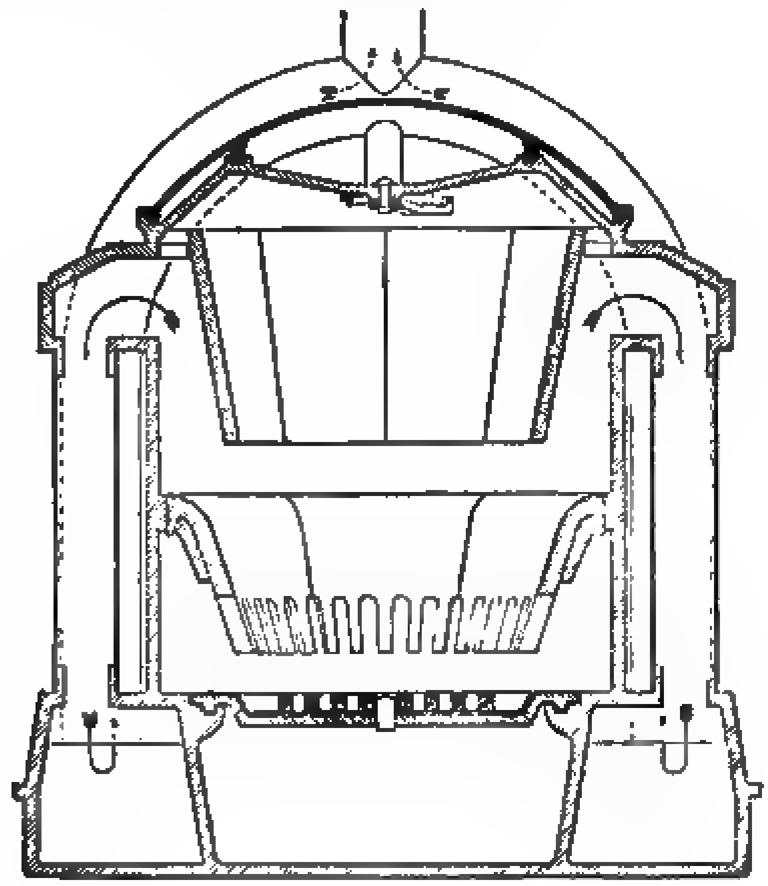

4052.

the top plane of the fire-chamber. Such constructions were patented both in France and England by a Mr. Walker as early as 1840.

In 1832 Dr. Eliphalet Nott patented and manufactured to a considerable extent a construction known as the "Nott stove," Fig. 4052. This was a true "base-burner," because it burned at the base only. The outlet from the fire-chamber was about on a level with the surface of the grate, and the products of combustion passed downward, thence horizontally through this outlet to the exit-pipe.

The next stove of this class that appeared was also a true "base-burner" for the same reason: the fire burned at and from the base. It was patented by Dennis G. Littlefield, and is represented

in Fig. 4053. The magazine fire-pot *A* is a continuous cylinder of nearly uniform size, supported upon a floor or ring, in the centre of which is placed the grate. This cylinder is surrounded by a case of partly cast and partly sheet iron, with an intervening chamber of 2 to 4 in., depending upon the size of the stove. The lower portion of the cylinder, for 5 to 8 in. in height from the base, is provided with wedge-shaped slots tapering upward, which leaves bars or fingers tapering downward, between which the products of combustion pass obliquely into the chamber formed by the inner cylinder and the outer case, thence upward, surrounding the former, to the exit. On all sides of the stove, and opposite to these slots, there are placed in the outer case windows of mica for illumination from the incandescent coal thus exposed. A fire can be retained in this stove from 6 to 12 days without attention, and without the consumption of much coal or the radiation of much heat.

Most "base-burners," or more properly "magazine stoves," have been greatly improved by the introduction of what are known as the "anti-clinker" devices patented by Foster, Moore, Frost, Hunt, and Perry. The essential features of these devices are as follows: 1. Placing the grate in a plane below the base of the fire-pot, so that a slicer can be passed over the surface of the former, for the purpose of removing clinkers and other refuse; 2. Constructing a space between the edge of the grate and the wall of the stove, through which this refuse may drop into the ash-pan; 3. Constructing the grate to rotate and dump; 4. Placing in the outer case mica windows for illumination from the incandescent coals that are exposed in the space between the pot and the grate. The special

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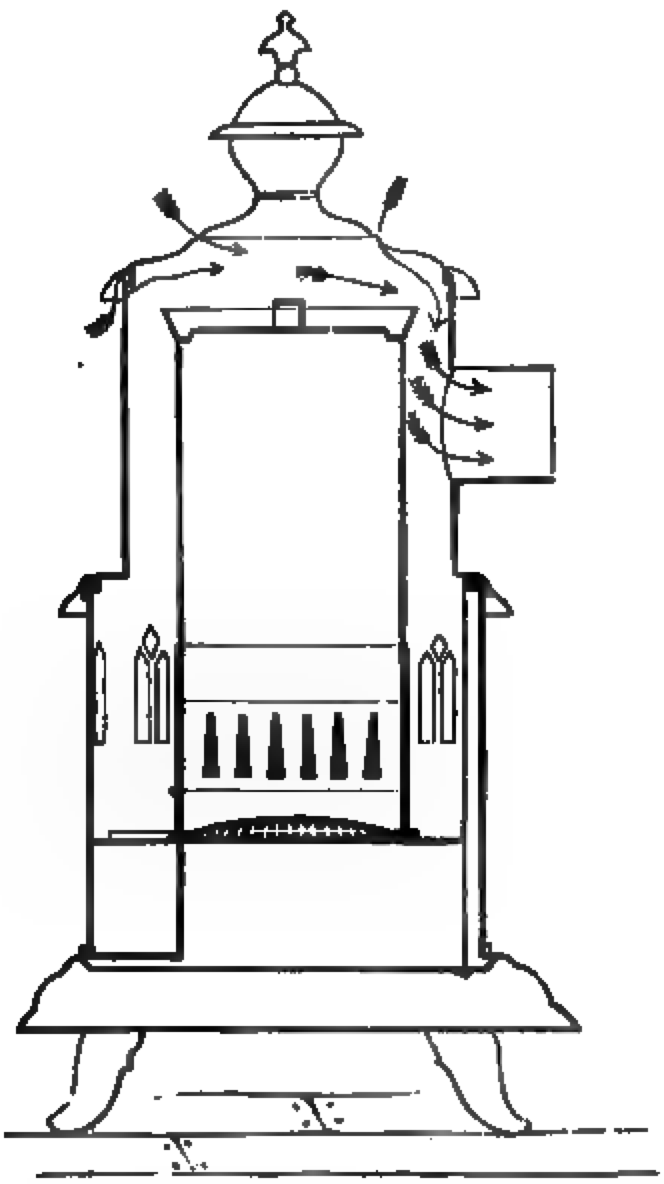


4054.

advantages derived from the introduction of a magazine for reserve fuel are: 1. The saving of labor by the infrequent requirement to supply fuel; 2. The regularity and uniformity with which it is fed to the fire; 3. The perpetuity of the fire. The principle has frequently been applied to cooking stoves with practical success; but they have never become popular.

The stove illustrated in Fig. 4054 contains these improvements, and may be regarded as a type of the best class of the modern American magazine stove.

Cooking Stoves.—The term "range" is commonly applied in this country to cooking stoves bricked in at the sides, or otherwise permanently built into the house. The ordinary range is simply a fire-chamber lined with fire-brick, and having at one side a water-back or iron chamber through which water is conducted to be heated on its passage for household uses. The ovens are usually placed on each side of the fire-chamber, and are provided with dampers which allow the heat to pass around them or be shut off as desired. Some ranges are constructed with so-called elevated ovens, these compartments being placed over the range and heated by suitable flues. Ranges have flat tops, in which are apertures of various shapes to enable cooking vessels and implements to be adjusted to the fire.

Cooking stoves proper are portable, and need only suitable connection with the water-pipes and chimney-flues to render them ready for immediate use. They exist in a variety of forms in the

United States, and a great amount of ingenuity has been expended in the improvement of their construction. The two forms presented in Figs. 4055 and 4056 are representative of the class.

Fig. 4055 is the Burke patent hot-air cooking stove, manufactured by Messrs. Burke & Conway of New York. *A* is the fire-box, with a portion of the interior wall of the front air-chamber removed; *B* is the top smoke-flue; *C*, the end smoke-flue; *D*, the bottom smoke-flue; *E*, the smoke-pipe, conveying the products of combustion to the chimney; *F*, the register through which the air is admitted to the hot-air chamber *G*, surrounding the fire-box. *H* is the top hot-air chamber; *L*, the back hot-air chamber, from which the hot air passes directly into the oven through the perforated distributing interior back-oven plate *M*. *N* is the interior front-oven hot-air distributing plate. *R* is the lower front hot-air chamber, whence the hot air is drawn through the automatic damper *T* to the fire to support combustion, and is thence carried around the oven to the chimney. *W* is the ash-sifter; *X*, the ash-drawer; and *Y*, the hot closet. In the engraving the white arrows indicate the circulation of the hot air, and the dark ones that of the products of combustion.

4055.

Fig. 4056 represents the Magee cooking stove, made by the Magee Furnace Company of Boston, Mass. The different parts are named in the engraving. Air is admitted into a chamber formed by the auxiliary plates *A*, and thence, after it becomes heated, it passes through the tubes *B* into the oven at *C*. After traversing the oven the air is drawn into the back of the fire-pot through apertures in the plate *D*.

Gas-Stoves.—Attachments to illuminating fixtures for simple heating, as of water or food, undoubtedly somewhat preceded the larger employment of gas, either for general cooking purposes or for warming. The natural succession has been the construction of apparatus for intense and direct heat for the preparation of food, and for continued and diffused heat for warming alone. Such apparatus has taken shape in a wide range of gas-stoves, designed and adapted for their special uses; gas reflectors or radiators; and special fixtures for heating in the form

of gas-logs, so called, being semblances of fuel in log form in metal, asbestos, etc., and supplied with gas-piping, for fireplace use. Such use of gas, and hence the manufacture of conveniences therefor, appear to be in the main confined to the United States, especially as regards the larger forms of apparatus. Nearly all gas-stoves involve modifications of the Bunsen burner, by means of which air is allowed to mingle with and thus increase the heat of the flame. It is yet a matter of some doubt whether the products of combustion, as occurring under circumstances where the direct flames of the burning gas impinge upon metal surfaces, are not a source of contamination from the large number of particles set free, which more or less seriously affect the air of our rooms. The requisites deemed essential by the judges at the Centennial Exhibition to secure approval and award were such thorough construction of parts as to render the escape of gas before reaching the burner impossible, such adjustment of jets as to secure a full supply of oxygen to the flame, and such disposition of the flame as to prevent the superheating of large metal surfaces. The gas-stoves manufactured in Philadelphia in a variety of forms have the serviceable and attractive feature, as applied to warming purposes, of a burnished reflecting surface, heightening in marked degree the radiating power, and lending an effect of geniality, of which this form of heating apparatus was previously quite barren. It is probable that efforts to increase the completeness of combustion and the radiating effect will be in the future the direction in which improvement will be made. That an abundant supply of the cheaper gases for consumption in this way may yet be furnished in convenient form, is also a desideratum toward which effort will no doubt be directed. A lessened cost of fixtures is also to be aimed at.

HOT-AIR FURNACES.—The requirements of a furnace *per se* are determined by certain well-ascertained data in chemistry, metallurgy, and philosophy; and as from time to time these data have been established, the effort in the construction of hot-air furnaces has been to give them recognition and adaptation. Some of these determining facts, as affecting construction and associate conditions, are worthy of a brief enumeration as the *rationale* of the somewhat rigorous demands made by the judges of Group XIV. at the Centennial Exhibition upon all furnaces exhibited. Among them are: 1. The ascertained power of very highly heated metal and other surfaces to slightly abstract the moisture from the atmosphere—in other words, to promote evaporation and to certainly change the relative humidity of the air by expansion; 2. The ascertained capacity of combustion to produce from fuel, notably from anthracite coal, large amounts of carbonic-acid and carbonic-oxide gases, with sulphurous acid and water vapor: 3. The fact that, when the combustion of anthracite is complete, the products are carbonic-acid gas and water, with slight sulphur fumes; 4. The fact that combustion rarely is complete in heating appliances, and never unless the supply of air passing over and through the fire is abundant; 5. The fact that carefully conducted experiments, by such scientists as Bernard, Guérand, Taylor, Watts, Leblanc, and Chenot, show that carbonic acid to some extent, and carbonic oxide to a powerful degree, are, when respired—either of them alone, but especially when mixed—of the character of narcotic poisons; 6. The certainty, as established by Ste.-Claire Deville and Troost, of the French Academy, that certain metals, especially cast iron, when heated to a dull red heat, permit the passage of gases directly through their substance, owing to the arrangement of their molecules or atoms; 7. The fact that, from the expansions and contractions occurring under the alternations of high and low degrees of heat, iron castings must be more or less poorly in coaptation, the passage of gases through their joints being but little retarded, while cast iron is also noticeably defective and porous in structure; 8. The fact that the denser metals, like wrought iron, contain a large per cent. of carbonic oxide—a fact which, though its relations are not yet understood, seems in some way to facilitate the passage of the carbonic oxide produced in combustion into dwellings.

The effort of the group, in view of these determinations of science, became chiefly to seek for the most successful adaptations of the principles involved, and to bestow highest commendation upon such as should possess them in the highest degree with the best associate conditions of convenience and economy. To this end it was determined to require of any hot-air furnace that to receive fullest commendation it should combine the following features: 1. It must be arranged for taking its supply of fresh air from outdoors, because only such fresh air is fit for supply to dwelling-apartments. 2. It must, to be most satisfactory, have least interference with free combustion and the escape of the product of combustion into the chimney; i. e., no damper in the smoke-flue, and no provision for the cooling of the flue by admission of air between the fire and chimney, e. g., as by a regulator; because to secure the removal of the dangerous elements, especially carbonic-oxide gas, complete combustion, and hence ready conversion into and utility as carbonic-acid gas, must be retarded by no agencies like these. 3. It must have its dome of wrought iron thoroughly bolted: first, because of its avoidance of leaks in joints; and second, because of its apparently lesser permeability to gases under heat. 4. It must have good castings, and, so far as possible, horizontal joints: first, because the necessity for the absence of "pin-holes" and like defective structure is apparent; and second, because there is less expansion and contraction, and less separation and escape of gases, with horizontal than with vertical joints, and fittings are more perfect. 5. It must have only fire-brick or soapstone walls in contact with its fire: first, because of the lessened evaporation thus caused; second, because the dull red heat of iron, so productive of carbonic oxide, is thus avoided; and third, because of the absence of gas-escape as occurring with the cast-iron pot. 6. It must have the most ample provision for the direct supply of air through and above the fire-pot, so arranged as to best impinge upon the combustion points, because of the absolute necessity for its presence to effect complete combustion, and hence the most rapid conversion of carbon into carbonic-acid gas, and the largest economy of fuel. 7. It must provide for a sufficient supply of moisture: first, because in no other way can the tendency to evaporation from the atmosphere which, under some conditions and in some climates, the furnace induces, be counteracted; and second, because this element is imperatively demanded for conditions of health. 8. It must have a large cylinder as proportioned to the fire-pot, because thereby the avoidance of a high temperature of the overarched iron is aided. 9. It should, if

the previously-named conditions are fully secured, be provided with a non-conducting fire-proof encasement, as of hollow tile, brick, or similar substance, for the conservation of locally-radiated heat, but not unless these conditions are secure: first, because such conservation is a prime feature of economy, a point which must always operate with either the purchaser or the scientist for obvious reasons; second, because the heating thereby of the cellar, where furnaces are generally located, is as a rule undesirable, beyond the point of simple dryness; and lastly, the reason for not having such encasement unless the dome be tight, etc. (see 1, 2, 3, 4, 5, 6, 7, and 8), is that the escape of deleterious gases into the larger area and more ample dilution of oxygen in the cellar, and freer exit to open air, must be far preferable to their concentrated conduct to the living apartments above. 10. It should have the most effective and convenient arrangement for the abstraction of clinkers and stirring up of the fire mass: first, because of the better combustion thereby secured; and second, because of the more even and better regulation of temperature, in addition to the merits of ease in its care. 11. It should combine the fullest and at the same time the simplest appliances for the control and removal of ashes, dust, and soot, as matters of convenience and as promoting the efficiency of the furnace.

The Boynton Furnace, made by Messrs. Richardson, Boynton & Co. of New York, is represented in Fig. 4057, in which its construction is clearly shown. Its chief advantages are the absence of joints and the heaviness of the castings embodied in it. The cold air follows the course of the arrows, entering from beneath the brick casing, and becoming warmed by contact with the dome and radiator before passing off by the flues.

The Magee Furnace, constructed by the Magee Furnace Company of Boston, is represented in Fig. 4058. It is made of wrought iron, with closely-bolted joints. The fire-pot is larger in size than is usual in cast-iron furnaces, and the dome is continuous and contains no air-flues, as is generally the case in furnaces of this description. The smoke-flue is placed on one side, and has a continuation over the feed-door which carries off any smoke or gas that otherwise might escape on opening the door. The cold-air flue is at the bottom, and the air is heated by direct contact with the dome. The arrows indicate the course of the hot air.

The Fire-Queen Furnace.—Fig. 4059 represents the Fire-Queen furnace, manufactured by Stewart,

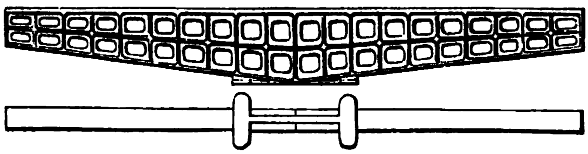
Peterson & Co. of Philadelphia. It consists of a cylindrical body of iron, in which the fire-pot is placed. Entirely surrounding this body, with the exception of a small portion at the base, is a shell of iron, a space being left between in which the air is heated and distributed to appropriate flues. A second casing surrounds the one mentioned, and forms the external body of the furnace. Through an opening in the top of this casing the cold air is introduced, getting gradually heated as it descends to the bottom, where it enters the main ascending hot-air chamber, thus making a double circuit around the body of the furnace, keeping the outside cool, and preventing any cold air from passing through the furnace into the hot-air distributing pipes. It is provided with a lever-grate which is moved on anti-friction rollers, and can be cleared from ashes without opening the fire-door or ash-pit door. The grate moves from front to back, and can be emptied at either end of the ash-pit when necessary. The fire-pot is lined with fire-brick.

Eickemeyer's Furnace, devised by Mr. R. Eickemeyer of Yonkers, N. Y., is represented in Fig. 4060. The surface of the grate can be increased or diminished by simple mechanism, to adapt it to the draft. The fire-box, ash-pit, etc., are entirely inclosed in a wrought-iron casing, outside of which the air to be heated circulates, and at the same time is entirely shut off from contact or possibility of mingling with the gases of combustion.

STRAIGHT-EDGE. The straight-edge is employed for the same purposes as a surface-plate. (See PLANOMETER.) It is in fact a long and narrow surface-plate, trued by the same process. To be finished accurately, it must be tested by laying on edge as described in the remarks upon surface

plates. The ribbed form shown in Fig. 4061 is given to the straight-edge, to enable it to resist deflection from its own weight as much as possible. Both straight-edges and surface-plates are best made of cast iron, which is found to suffer the least abrasion under the duty required of such tools.

4061.



STRENGTH OF MATERIALS. The term "strength of materials," in its widest sense, as used by many authorities, does not include merely what is known as the absolute or ultimate strength—or the resistance, expressed in pounds per square inch or other unit, to final rupture—but also the resistance within certain limits to distortion short of final rupture, as the elastic limit and the point of permanent set; the safe load; the resistance to steady and to suddenly applied loads; and the resistance to repetitions of loads and to shocks and vibrations. It also includes the amount of distortion of the material before final rupture, commonly called ductility; and the property of returning toward its original form after temporary distortion, or elasticity. The external forces applied to materials, tending to cause their rupture or alteration of form, are called *stresses*. These are respectively termed tensile, compressive, transverse, torsional, and shearing.

The practical applications of formulæ and data derived from experiment relative to strength of materials appear under the following headings: To machine designing in general, MACHINE CONSTRUCTION, PRINCIPLES OF; strength of armor, ARMOR; of chain cables, CHAIN; of bridge structures, BRIDGES; of cements, concretes, brick, etc., CONCRETES AND CEMENTS; of structures in wood, CARPENTRY; of foundations, FOUNDATIONS; of journals and bearings, JOURNALS; of metal as resisting punching and shearing, PUNCHING AND SHEARING MACHINERY; of steam machinery, ENGINES, STEAM, PROPORTIONS OF PARTS OF, and LOCOMOTIVES, PROPORTIONS OF; of riveted joints, stays, plates, etc., BOILERS, STEAM; of shafts, SHAFTING; of wire, WIRE; and of alloys, ALLOYS. As to methods of determining strength of materials, see TESTING MACHINES.

TENSILE STRESS.—The resistance of materials to tensile stress is the one which receives most attention, as it is called into play more frequently than any other except compressive, and is considered to be in some measure an index to all other resistances. It is usually determined by means of an apparatus known as a testing machine, the methods of using which are fully described under TESTING MACHINES. It may be here pointed out that differently constructed machines of this class have given widely different results; that the form of specimens broken, the mode of placing them in the machine, and the time during which they have been subjected to stress, also greatly affect the accuracy of data; and that consequently wide disagreements are encountered in the figures given by different authorities as representative of standard resistances for various materials. Hence, the careful engineer will wherever practicable individually test and determine the strength of the material he proposes to use, and will regard such data as are below given rather as approximate and subject to verification than as precedents to be adopted and blindly followed.

The coefficient of elasticity, or *modulus of elasticity*, is a term expressing the relation between the amount of extension or compression of a material and the load producing that extension or compression. It may be defined as the load per unit of section divided by the extension per unit of length; or, the reciprocal of the fraction expressing the elongation in one inch of length, divided by the pounds per square inch of section producing that elongation. Thus, let P be the applied load, K the sectional area of the piece, L the length of the part extended, l the amount of extension, and E the coefficient of elasticity. Then $\frac{P}{K}$ = the load on a unit of section, and $\frac{l}{L}$ = the elongation of a unit of length. E therefore $= \frac{P}{K} \div \frac{l}{L} = \frac{PL}{Kl}$. The elastic limit is that point at which the extensions cease to be proportional to the stresses and begin to increase in a greater ratio.

The ultimate strength is the maximum resistance offered to rupture. The *proof strength* is a less degree of resistance which the body may safely offer when tested. The *working load* is some fractional part of the ultimate strength which may be selected as giving perfect safety against anticipated strains for an indefinite period. The *factor of safety* is the ratio of the ultimate strength to the working load.

The proof-set is usually and should be always below the elastic limit, i. e., the point at which set becomes proportional or nearly so to the distortion produced by the applied force. It is generally about one-half to one-third the ultimate strength. The ultimate strength or breaking load of any piece is measured by the product of the area of the fractured section into the tenacity of the material of which it is composed; or $P = TK$, and $K = \frac{P}{T}$, where P represents the breaking force, T the tenacity of the material, and K the area of section. Values of T are given in the accompanying table of coefficients of resistance. The very best grades should have values 20 per cent. higher. P and T are taken in pounds per square inch. When thin cylinders are exposed to internal pressure, as in steam-cylinders, boilers, etc., the bursting pressure may be determined by multiplying the thickness of the shell by the tenacity of the material, and dividing by the semi-diameter; or $P = \frac{Tt}{r}$, where P = pressure, t = thickness, T = tenacity, and r = radius of cylinder.

Tensile Strength of Iron and Steel.—D. K. Clark gives the following recapitulation of data from a large number of experiments:

Cast Iron.—The ultimate strength of cast iron ranges from 5 to 7½ tons per square inch—first meltings, specimens under one inch in thickness. For thicker castings the strength diminishes. The ultimate tensile strength is increased by repeated remeltings to from 15 to 20 tons per square inch. The elastic strength is practically the ultimate tensile strength.

Wrought Iron.—The ultimate tensile strength of rolled bar iron varies from 22½ to 30 tons; rivet-iron, from 24 to 27 tons; plates, from 20 to 23 tons, about 1 ton less crosswise than lengthwise the fibre. The strength is reduced more than 1 ton by annealing. For a wrought-iron round rod of any diameter, the square of the diameter in quarter inches is about the breaking weight in tons.

Steel.—The ultimate tensile strength of rolled bar steel varies from 30 to 50 tons per square inch. The average tensile strength may be taken at 35 tons. The ultimate strength of steel plates is from 22 to 32 tons, according to the proportion of constituent carbon. The strength is the same lengthwise or crosswise. Annealing reduces the tensile strength of steel plates by 1½ or 2 tons. The most remarkable specimen of cast steel for tenacity which is on record was manufactured at Pittsburgh, Pa. It was tested in the Navy Yard at Washington, D. C., and was found to sustain 242,000 lbs. per square inch. The tensile strength of chrome steel, according to report of Capt. J. B. Eads, C. E., on tests of that metal for use in the St. Louis bridge, was found to average for 12 specimens 179,980 lbs. per square inch.

Compressive Stress, or push applied to a piece of material, is a force which tends to shorten it. While the effect of tensile stress is always to produce rupture or separation of particles in the direction of the line of strain, that of compressive stress may be to cause the material to fly into splinters, to separate into two or more wedge-shaped pieces and fly apart, to buckle, bulge, or bend, or to flatten out and utterly resist rupture or separation of particles. There exists great confusion among authorities as to the use of this term, and the data given as representing compressive strengths of various materials are far from reliable. In no department of mechanics is original investigation more needed or more to be desired. The figures in column C of the table give approximately the resistance to crushing when bending does not occur. Hodgkinson, in experiments on long square pillars, found that the compressive strength varied as the 3.59 power of the side of the square, as a mean result; the extremes being the 2.69 and the 4.17 powers. From his experiments the following table of the absolute strength of columns was obtained, in which $P =$ crushing weight in gross tons, $d =$ the side of the column in inches or external diameter, $d_{,} =$ the internal diameter of the hollow in inches, and $l =$ the length in feet:

KIND OF COLUMN.	Both Ends Rounded, the Length of the Column exceeding 15 times its Diameter.	Both Ends Flat, the Length of the Column exceeding 30 times its Diameter.
Solid cylindrical columns of cast iron.......... ..	$P = 14.9 \frac{d^{3.76}}{l^{1.7}}$	$P = 44{\cdot}16 \frac{d^{3.55}}{l^{1.7}}$
Hollow cylindrical columns of cast iron..........	$P = 13 \frac{d^{3.76} - d_{,}^{3.76}}{l^{1.7}}$	$P = 44.84 \frac{d^{3.55} - d_{,}^{3.55}}{l^{1.7}}$
Solid cylindrical columns of wrought iron........	$P = 42 \frac{d^{3.76}}{l^2}$	$P = 133.75 \frac{d^{3.55}}{l^2}$
Solid square pillar of Dantzic oak..............	....	$P = 10.95 \frac{d^4}{l^2}$

These formulæ apply only in cases in which the length is so great that the column breaks by bending and not by simple crushing. If the column be shorter than that given in the table, and more than four or five times its diameter, the strength is determined by the following formula: $W = \frac{PCK}{P + \frac{3}{4}CK}$; in which $P =$ the value given in the preceding table, $K =$ the transverse section of the column in square inches, $C =$ the modulus for crushing in gross tons per square inch, and $W =$ the strength of the column in gross tons. The modulus for crushing is defined as "the pressure which is necessary to crush a piece of any material whose section is unity and whose length does not exceed from 1 to 5 times its diameter." The first and second formulæ given below were deduced by Lewis D. Gordon from Hodgkinson's experiments; they show the total breaking weight of a cast-iron column. The succeeding formulæ for strength of columns of wrought iron and steel were constructed on the basis of Gordon's formula by the authorities named:

For solid or hollow round cast-iron columns, $W = \dfrac{36\,a}{1 + \dfrac{r^2}{400}}$.

For solid or hollow rectangular cast-iron columns, $W = \dfrac{36\,a}{1 + \dfrac{r^2}{500}}$.

For columns of angle, tee, channel, or cruciform iron, $W = \dfrac{19\,a}{1 + \dfrac{r^2}{900}}$ (Unwin).

For solid round column of mild steel, $W = \dfrac{30\,a}{1 + \dfrac{r^2}{1400}}$ (Baker).

For solid round column of strong steel, $W = \dfrac{51\,a}{1 + \dfrac{r^2}{900}}$ (Baker).

For solid rectangular column of mild steel, $W = \dfrac{30\,a}{1 + \dfrac{r^2}{2480}}$ (Baker).

For solid rectangular column of strong steel, $W = \dfrac{51\,a}{1 + \dfrac{r^2}{1600}}$ (Baker).

In these formulæ $W =$ the breaking weight in tons of 2,240 lbs., $a =$ sectional area of the material in square inches, and $r =$ the ratio of the length to the diameter, the diameter being the least dimension of the section, or that on which it is most flexible.

TRANSVERSE STRESS.—There exists no such discrepancy in the published figures of transverse strength of beams as in those of the compressive strength of columns according to different authorities. The transverse strength of beams is calculated from the following formulæ:

$W = \dfrac{K\,b\,d^2}{L}$ and $W = \dfrac{K\,A\,d}{L}$, for beams fixed at one end and loaded at the other.

$W = 2\,\dfrac{K\,b\,d^2}{L}$ and $W = 2\,\dfrac{K\,A\,d}{L}$, where fixed at one end and uniformly loaded.

$W = 4\,\dfrac{K\,b\,d^2}{L}$ and $W = 4\,\dfrac{K\,A\,d}{L}$, where supported at both ends and loaded at centre.

$W = 8\,\dfrac{K\,b\,d^2}{L}$ and $W = 8\,\dfrac{K\,A\,d}{L}$, where fixed at both ends and loaded at centre.

$W = 8\,\dfrac{K\,b\,d^2}{L}$ and $W = 8\,\dfrac{K\,A\,d}{L}$, where supported at both ends and uniformly loaded.

$W = 12\,\dfrac{K\,b\,d^2}{L}$ and $W = 12\,\dfrac{K\,A\,d}{L}$, where fixed at both ends and uniformly loaded.

Here $W =$ breaking weight in pounds, $K =$ a coefficient which varies with every change in form of cross-section of the beams, $d =$ depth of beam in inches, $b =$ breadth in inches, $A =$ area of cross-section of the beam at point of rupture in square inches, and $L =$ length between supports in feet. The values of K given in the table, where the beams are of rectangular section, fixed at one end and loaded at the other, are obtained from various sources. For other than rectangular sections the following may be taken as the values of K for cast iron: Shape, ●; value, $K = 500$. Shape, I, equal flanges; value, $K = 520$. Fairbairn, ⊥; value, $K = 580$. Hodgkinson, I; value, $K = 850$. The following values are given for wrought iron: rolled rails, , 600; Fairbairn's riveted beam, , 900; box-beam, , 1,000. For the wrought-iron I beam, when supported at both ends and uniformly loaded, the formula $W = \dfrac{8\,D\left(a + \dfrac{a'}{6}\right)S}{L}$ is used by some American manufacturers. $D =$ depth in feet; $a =$ area of flange in inches, $a' =$ that of "stem" or web; $S =$ stress per square inch of area, $a + \dfrac{a'}{6}$, in tons. The deflection, $S = \dfrac{.006\,W\,L^3}{\left(a + \dfrac{a'}{6}\right)d^2}$ when the load is applied at the middle, and $S = \dfrac{.004\,W\,L^3}{\left(a + \dfrac{a'}{6}\right)d^2}$ when applied uniformly. The depth D is measured between the centres of gravity of the flanges. In such beams it is customary to allow as maxima 10,000 lbs. per square inch in tension and 6,000 to 8,000 in compression. Deflection should not exceed one-thirtieth of an inch per foot of length in any structure.

A very full discussion of the subject of transverse strain appears in "Transverse Strains," Hatfield, New York, 1876. See also the works on strength of materials quoted at the end of this article for theories on the relation between transverse strength and tensile and compressive strength.

Shearing Stress is a force tending to draw one part of a solid substance over another part of it, the applied and resisting forces acting in parallel planes which are very near each other. The total resistance to ultimate shearing when all parts of the resisting surface are brought into action at once is found to vary directly with the section; so that if $K =$ the area of the section subjected to this stress, the total resistance will be $K\,S$. The value of S has been found for several substances, the principal of which are as follows:

Shearing Strength of Materials (compiled by Wood).

METAL.	S in lbs. per sq. in.
Fine cast steel	92,400
Rivet steel	64,000
Wrought iron	50,000
Wrought-iron plates, punched	51,000 to 61,000
Wrought-iron hammered scrap, punched	44,000 to 52,000
Cast iron	30,000 to 40,000
Copper	33,000

WOOD. With the fibres.		Across the fibres.	
White pine	480	Red pine	500 to 800
Spruce	470	Spruce	600
Fir	592	Larch	970 to 1,700
Hemlock	540	Treenails, English oak	3,000 to 5,000
Oak	780		
Locust	1,200		

It will be seen from these results that the shearing strength of wrought iron is about the same as its tenacity; of cast steel, a little less; of cast iron, double its tenacity and about two-fifths of its crushing resistance; and of copper, about two-thirds of its tenacity. Clark considers that the shearing strength of wrought iron may be taken at about four-fifths of its tenacity. The resistances of metals to shearing in shearing machines are considered under PUNCHING AND SHEARING MACHINES.

Torsional Stress is computed by the formula $W = S'\,\frac{D^3}{R}$; $D = \sqrt[3]{\frac{W R}{S'}}$; where $W =$ breaking weight in pounds, $D =$ diameter of shaft in inches, and $R =$ length of lever-arm in feet. The coefficient S' is very nearly proportional to the tenacity of the material, where the torsion is equal in degree.

Resilience is a term introduced by Dr. Young. It is measured by the amount of work performed in producing the maximum strain which a given body is capable of sustaining, and is the quality of primary importance where shocks are to be sustained. Mallet's coefficient of resilience is the half product of the maximum resistance into the maximum extension. But for tough metals it is equal approximately to two-thirds the product of the ultimate strength of the material by the distance through which the body yields before the straining force. For very brittle materials it is measured by half that product. No material can resist the shock of a body in motion, unless it is capable of offering resilience equal to the amount of work performed in setting that body in motion at the given velocity; i. e., equal to the amount of energy stored in the moving mass at the instant of striking. In predicting the effect of shock, therefore, it becomes necessary to know the amount of energy stored in the moving body and the resilience of the resisting material. To meet a violent shock successfully, resilience, rather than mere strength, must be secured. As an instance, it is found that wrought iron of comparatively low tenacity but great toughness, capable of stretching considerably before fracture, is far superior to steel for armor for iron-clad ships; the latter has much greater strength, but also greater brittleness. Such calculations are not usually made in designing. Immunity from the injurious effect of shocks is secured by the use of a large factor of safety in proportioning parts exposed to them, by care during construction in the selection of tough resilient materials, and in management by carefully adjusting all parts, and applying the load so as to avoid jarring action as far as possible. If a weight, acting as a steady load, produces a given deflection or change of dimensions, it will require but half that weight suddenly applied to produce a similar effect, whether it be fracture or a stated alteration of form. The extension of ordinary wrought iron within its limit of elasticity is about .0001 per ton per square inch of section. The amount of extension before fracture by tension is given, with the finest quality of wrought iron, at 20 per cent., with medium quality 16 per cent., and it runs in some irons as low as 4 per cent. Cast iron of fair quality is elongated but a fraction of 1 per cent. The extension of steel varies with the amount of carbon, and nearly inversely as its tenacity. The following table is taken in part from Trautwine's "Engineer's Pocket-Book":

Ultimate Tensile Strength of Steel in Pounds per Sq. In., and Elongation in Inches, before Breaking.

SPECIMENS.	Per Cent. of Carbon.	Breaking Weight.	Elongation.	Resilience.	SPECIMENS.	Per Cent of Carbon.	Breaking Weight.	Elongation.	Resilience.
No 1	.33	68,100	.098	4.450	No. 6	.63	109,800	.071	4,770
No. 2	.48	76,160	.089	4.970	No. 7	.74	101,920	.080	3.400
No. 3	.48	84,000	.089	5,040	No. 8	.84	123,200	.080	6.580
No. 4	.53	95,200	.080	5,080	No. 9	1.00	134,400	.071	6.86
No. 5	.58	92,960	.058	3,600	No. 10	1.25	154,560	.044	4,580

NOTE.—The specimens tested were steel bars of different grades made from pure Swedish iron, and each bar was turned to a diameter of 1 inch for a length of 14 inches.

In the larger table on page 835, the ultimate resilience of metals is given as tested in the Stevens Institute of Technology, Hoboken, N. J. Phosphor-bronze considerably exceeds ordinary bronze in ductility and resilience.

Influence of Density and Temperature on Strength.—Heating wrought iron within certain limits, and then cooling under stress, increases its strength by relieving internal strain. Cold rolling and wire-drawing increase it, in some cases, 100 per cent. Mr. Dean of Boston and Uchatius of Vienna have similarly increased the strength and elasticity of bronze. Overheating, annealing, and cold hammering decrease its strength. Cast iron of open structure and low density is increased in strength by successive remeltings, sometimes to the amount of 100 per cent., over pig metal. Casting under a head, or under considerable pressure, similarly benefits both cast iron and cast steel. Sir Joseph Whitworth produced a steel of extraordinary strength and toughness by casting under heavy pressure. The internal strain consequent upon sudden cooling, or upon cooling awkwardly-shaped castings, seriously reduces their strength, and sometimes produces actual fracture. The character of cast iron is largely determined by its density, 7.2 to 7.3 representing the best limits for ordinary practice. Cold wrought iron is more than twice as strong as red-hot. Strength, ductility, and resilience increase with diminishing temperatures, when the materials are of good quality. Cold-blast cast iron is usually stronger than hot-blast iron made from the same ores. Copper loses 25 per cent. of its tenacity at 550° F., 50 per cent. at 810°, and 67 per cent. at 1,000°, the diminution of tenacity varying nearly as the square root of the third power of the temperature. Metals in large masses have usually less density and strength than when worked into sheets, bars, or wire. Wrought iron is particularly liable to loss of strength in large forgings. Bars 2 in. in diameter being made of the same metal as other bars 1 in. in diameter, the latter are sometimes found to have 20 per cent. more strength. Steel exhibits even greater differences.

Resistance to Penetration.—Indentation is resisted by wrought iron nearly in proportion to its thickness. Fairbairn found the force necessary to push a blunt point or a ball 3 in. in diameter through boiler-plate one-quarter of an inch thick to be 17,000 lbs., and nearly equal to that required to drive the same instrument through a 3-inch oak plank. Resistance of armor-plate to penetration by shot varies, if the plate be well backed, as the square of the thickness, within the limit of moderate thickness. The material should be strong and ductile.

Strength of Members of Structures.—Generally, in designing machines or parts of machines, they should be so proportioned that all parts will have factors of safety of nearly equal value. Economy of material is thus secured, and also the very important advantage, where exposed to severe shock or sudden strains, of utilizing the resilience of the whole machine in resisting them. Forms of uniform strength should therefore be used wherever possible. Suspension-rods of uniform strength must have a greater section at the point of support than at the point of attachment of the load, as the upper portions carry not only the load but the weight of the lower part of the rod. Pump-rods and wire ropes for deep mines are for this reason made tapering, with the largest section at the top. Care should always be taken that the pieces connected and their fastenings are, when possible, equally strong. Tall columns are slightly swollen at the middle portion in order that they may be equally liable to break at all points; and the Hodgkinson form of cast-iron beams, and the Fairbairn (I) form of section of wrought-iron beams, are given their peculiar shapes in order that no surplus material may exist in either top or bottom flange. Beams of uniform strength, when fixed at one end and loaded at the other, if of uniform depth, are triangular in plan. If uniformly loaded, they represent in plan a pair of parabolas whose vertices touch at the outer end. When of uniform breadth, their vertical sections are parabolic in the first case, and triangular in the second. Beams of uniform depth, supported at the ends and loaded at the middle point, are in plan a pair of triangles with a common base at the load. If uniformly loaded, the plan is a pair of parabolas with their bases at the middle of the beam. When supported at the ends and uniform in breadth, they are in vertical section a pair of parabolas, in the first case with vertices at the ends and bases meeting at the load, and in the last case semi-ellipses extending between the points of support. In building bridge-girders, economy of material is secured by the use of isosceles bracing set at angles of 45°. In vertical and diagonal bracing, the proper angle for diagonals is 55° measured between the diagonal and the vertical. The amount of resistance of a cylinder to rupture by torsion is nearly double that to breaking across. Bolts exposed to shocks and sudden strains, as when used as armor-plate fastenings, are found to resist much more effectually where resilience is secured by turning down the shank to the diameter of the bolt at the bottom of the thread, or otherwise creating a uniform area of section between head and nut.

WORKING STRENGTH OF MATERIALS—FACTORS OF SAFETY.—*Cast Iron.*—Mr. Stoney recommends one-fourth of the ultimate tensile strength for dead weights, one-sixth for cast-iron bridge-girders, and one-eighth for crane-posts and machinery. In compression free from flexure, according to Mr. Stoney, cast iron will bear 8 tons per square inch; for cast-iron arches, 3 tons per square inch; for cast-iron pillars, supporting dead loads, one-sixth of the ultimate strength; for pillars subject to vibration from machinery, one-eighth, and for pillars subject to shocks from heavy loaded wagons and the like, one-tenth, or even less where the strength is exerted in resistance to flexure.

Wrought Iron.—For bars and plates, 5 tons per square inch of net section is taken as the safe working tensile stress; for bar iron of extra quality, 6 tons. In compression, where flexure is prevented, 4 tons is the safe limit; in small sizes, 3 tons. For wrought-iron columns subject to shocks, Mr. Stoney allows a sixth of the calculated breaking weight; with quiescent loads, one-fourth. For machinery, an eighth to a tenth is usually practised; and for steam-boilers, a fourth to an eighth. Mr. Roebling says: "Long experience has proved beyond a shadow of a doubt that good iron, exposed to a tensile strain not above one-fifth of the ultimate strength, and not subject to strong vibration or torsion, may be depended upon for a thousand years."

Steel.—A committee of the British Association recommended a maximum working tensile stress of

Table of Coefficients of Resistance.

MATERIAL.	W. Weight per cubic foot.	T. Tension.	C. Crushing.	K. Transverse.	[illegible] Torsion.	E. Coefficient of elasticity.	R. Resilience.
METALS.							
Antimony	380	1,000	......	....	15	....	......
Bismuth	613	3,000	......	.....	50	....	......
Brass:							
Copper 10, zinc 1	535	22,000	[illegible]	...	200	6,000,000	6,000
" 5, " 1	525	30,000	160,000	240	500	9,000,000	8,000
" 2, " 1	525	24,000	......	.....	....	6,000,000	4,000
Fine drawn	565	60,000	165,000	...	1,000	14,000,000	15,000
Bronze:							
Aluminum 10, copper 90	480	70,000	135,000	.....	400	10,000,000	......
Copper 10, tin 1	535	36,000	......	....	500	11,000,000	6,000
" 8, " 1	528	40,000	......	.....	700	12,000,000	6,000
" 6, " 1	540	40,000	......	.....	.....	....	2,000
Copper:							
Cast	540	20,000	......	.....	350	[illegible]	[illegible]
Rolled	550	30,000	100,000	.....	400	....	......
Drawn	555	60,000	100,000	.....	750	....	......
Forged	559	40,000	100,000	220	600	3,750,000	40,840
Gold wire	1,210	20,000	35,000	.....	.....	....	......
Iron:							
Cast, pig	440	20,000	100,000	500	400	12	15
" hard	450	30,000	125,000	750	600	22	5
" tough	450	25,000	120,000	600	500	15	25
" gun iron	455	30,000	125,000	700	700	20	50
Wrought, bar	486	[illegible]	50,000	900	750	22	20,000
" sheet	486	50,000	60,000	700	650	25	15,000
" tank	480	45,000	65,000	600	600	25	10,000
" wire ⅛ inch	485	80,000	60,000	900	1,000	28	40,000
" large forging	475	40,000	40,000	500	500	20	10 000
Lead, cast	710	1,800	7,000	90	20	1	.. ..
" rolled	712	2,500	......	80	80	....	.. ..
Platinum	1,340	55,000	......	700	.....	....	......
Silver	654	40,000	......	500	....	....	......
Steel:							
Carbon 0·0035	489	65,000	80,000	800	[illegible]	25,000,000	35,000
" 0·0050	487	90,000	125,000	1,500	[illegible]	27,000,000	15,000
" 0·0075	484	100,000	150,000	2,000	1,350	29,000,000	10,000
" 0·0100	485	140,000	225,000	3,000	1,800	30,000,000	10,000
" 0·0125	485	160,000	250,000	5,000	2,000	31,000,000	5,000
Hardened in oil	....	200,000	350,000	7,000	3,000	33,000,000	.. ..
Rails	486	70,000	100,000	900	900	....	30,000
Plate	487	80,000	120,000	1,200	1,100	....	......
Blister	488	100,000	150,000	2,000	1,500	....	......
Shear	486	120,000	180,000	2,500	2,000	.....	5,000
Tin, block	455	4,000	15,500	50	60	4,500,000	2,500
" wire	460	7,000	......	50	[illegible]	....	......
Zinc, cast	437	2,500	......	30	80	13,000,000	500
" rolled	[illegible]	16,000	......	200	200	....	......
MINERALS.							
Brick, red	130	350	[illegible]	5	....	....	......
" "	135	800	2,000	19	14	....	......
Cement, 1 week	120	100	......	20	.....	....	......
" 1 year	120	[illegible]	2,000	5	60	....	......
Chalk	117	......	334	.....	.....	....	......
Glass, plate	158	9,420	......	.....	.....	....	......
Granite	165	1,000	10,000	25	960	....	......
Limestone	165	500	6,000	40	100	23,000,000	......
Marble	165	......	9,000	40	.....	25,000,000	......
Sandstone	150	200	5,000	15	800	....	......
Mortar	107	50	150	.....	.....	....	......
TIMBER.							
Acacia	47	16,000	......	140	.....	1,152,000	......
Apple tree	50	19,000	....	.....	.....	....	......
Ash	45	16,000	9,000	150	120	1,500,000	.....
Beech	50	16,000	6,000	120	110	1,400,000	......
Birch	50	15,000	6,000	130	....	1,500,000	......
Box	60	18,000	10,000	180	125	....	......
Cedar	56	11,500	6,000	100	100	....	......
Elm	37	13,000	10,000	75	....	700,000	.....
Fir, N. E	35	12,000	6,000	80	75	2,000,000	....
Larch	35	9,000	10,000	100	90	1,000,000	....
Lancewood	63	23,000	......	150	120	....	.....
Lignumvitæ	73	12,000	10,000	160	150	....	......
Locust	60	20,000	......	250	220	....	......
Mahogany	50	16,000	6,000	120	180	....	......
Maple	50	10,000	......	.....	.....	....	....
Oak	55	17,000	10,000	150	140	1,500,000	......
Pine	46	10,000	8,000	100	65	1,750,000	.....
Spruce	31	17,000	6,000	120	.....	1,600,000	......
Teak	45	15,000	12,000	180	150	2,400,000	......
Walnut, white	42	8,000	7,000	100	200	....	......
" black	[illegible]	8,000	8,000	150	180	....	......

9 tons per square inch. Mr. Stoney recommends for mild steel a fourth of the ultimate strength, or 8 tons per square inch. The limit for compression must be regulated very much by the nature of the steel, and whether it be unannealed or annealed. Probably a limit of 9 tons per square inch, the same as the limit for tension, would be the safe maximum for general purposes. In the absence of experiment, Mr. Stoney recommends that, for steel pillars, an addition not exceeding 50 per cent. should be made to the safe load for wrought-iron pillars of the same dimensions.

Timber.—One-tenth of the ultimate stress is an accepted limit. Timber piles have in some situations borne permanently one-fifth of their ultimate compressive strength.

Foundations.—Prof. Rankine says that the maximum pressure on foundations in firm earth is from 17 to 23 lbs. per square inch, and that on rock it should not exceed one-eighth of the crushing load.

Mason-work.—Mr. Stoney says that the working load on rubble masonry, brick-work, or concrete rarely exceeds one-sixth of the crushing weight of the aggregate mass, and that this seems to be a safe limit. In an arch, the calculated pressure should not exceed one-twentieth of the crushing pressure of the stone.

Rope.—For round ropes, the working load should not exceed a seventh of the ultimate strength, and for flat ropes one-ninth.

Resistance to Repeated Stress.—The law determined by Wöhler in 1858, after a long series of experiments, is that "Rupture may be caused not only by a steady load which exceeds the carrying strength, but also by repeated application of stresses none of which are equal to this carrying strength. The differences of these stresses are measures of the disturbance of continuity, in so far as by their increase the minimum stress which is still necessary for rupture diminishes." This law shows that the assumption that safety depends only on the maximum intensity of stress must be considered as erroneous. Wöhler determined that a bar which is alternately subjected to compression and tension will endure a much smaller number of repetitions of strain than the same bar subjected to an equal amount of either tension or compression alone. Certain bars of wrought iron and steel were equally safe to resist varying bending and tensile straining actions repeated for an indefinite time when the maximum and minimum stresses had the following values: For wrought iron, in tension only, from + 18,713 to + 31 lbs. per square inch; in tension and compression alternately, from + 8,317 to − 8,317 lbs. per square inch. For cast steel, in tension only, from + 34,307 to + 113,436 lbs. per. square inch; in tension and compression alternately, from + 12,475 to − 12,475 lbs. per square inch. + represents tension and − compression. For the discussion of Wöhler's law, see MACHINE CONSTRUCTION, PRINCIPLES OF.

The foregoing article contains many extracts from a series of essays on "Strength of Materials" by Mr. W. Kent, C. E., published in *Van Nostrand's Engineering Magazine*, vol. xx.; from "Rules, Tables, and Data for Mechanical Engineers," by D. K. Clark, London, 1877; and from the article on "Strength of Materials," by Prof. R. H. Thurston, in the "American Cyclopædia."

Works for Reference.—The literature on the strength of materials is exceedingly voluminous, including much that is of little value in the light of modern research. The following are among the standard works on the subject: "On the Strength of Cast-Iron Beams," Turnbull, London, 1832; "On the Strength and Stiffness of Timber," Turnbull, London, 1833; "On the Strength of Materials," Tate, London, 1850; "On the Strength of Cast Iron and other Metals," Tredgold and Hodgkinson, London, 1861; "Théorie de la Résistance des Solides," Belanger, Paris, 1862; "Résistance des Matériaux," Morin, Paris, 1862; "Experiments on Wrought Iron and Steel," Kirkaldy, London, 1864; "Leçons sur la Résistance des Matériaux," Navier, Paris, 1864; "Cast and Wrought Iron," Fairbairn, London, 1865; "The Elasticity, Extensibility, and Tensile Strength of Iron and Steel," Styffe, translated by Sandberg, London, 1865; "On the Strength of Materials," Barlow, London, 1867; "On the Strength of Beams, Columns, and Arches," Baker, London, 1870; "Tredgold's Carpentry," Hurst, London, 1871; "The Strength of Materials and Structures," Anderson, London, 1872; "New Formulas for the Loads and Deflections of Solid Beams and Girders," Donaldson, London, 1872; "Iron as a Material of Construction," Pole, London, 1872; "Applied Mechanics—Useful Rules and Tables," Rankine, London, 1872; "Civil Engineer's Pocket-Book," Trautwine, Philadelphia, 1872 (see latest edition); "Theory of Strains," Stoney, London, 1873; "Strains upon Bridge-Girders and Roof-Trusses," Cargill, London, 1873; "Strength, Elasticity, Ductility, and Resilience of Materials of Construction," Thurston, Philadelphia, 1874; "Resistance of Materials," Wood, New York, 1875; "Timber and Timber Trees," Laslett, London, 1876; "Elements of Machine Design," Unwin, London, 1876; "Fatigue of Metals," Spangenberg, New York, 1876; "Strength and Determination of Dimensions of Structures," Weyrauch, New York, 1877; "Reports of United States Board appointed to test Iron and Steel," Washington, 1879.

See also, for results of experiments, files of the *Journal of the Franklin Institute, Engineering, Engineer, Iron, Van Nostrand's Engineering Magazine, London Philosophical Transactions, Civil Engineer's and Architect's Journal, Proceedings Institute Mechanical Engineers* (British), *Comptes Rendus, Annales des Ponts et Chaussées, Transactions of the American Society of Civil Engineers, Proceedings of the Institute of Civil Engineers* (British), *Annals of Philosophy*, and *Journal of the Iron and Steel Institute.*

STRETCHING MACHINE. See CLOTH-FINISHING MACHINERY, and HAT-MAKING MACHINERY.

STÜCKOFEN. See IRON-MAKING PROCESSES.

SUGAR MACHINERY. The manufacture of sugar consists in the expression of the saccharine juice from the sugar-producing plants, the purification of the expressed juice, and the evaporation therefrom of the water so as to concentrate the sugar into crystalline form. The processes by which this is accomplished vary according to the quality of sugar to be made, or in other words according to the purity of the sugar required. Common-process sugar is made by evaporation in open pans; vacuum-pan or granulated sugar, by evaporation *in vacuo* in closed pans; and both varieties are made into refined or loaf sugar by certain processes hereafter described.

The present article deals with sugar manufacture solely in relation to the machinery used, and therefore does not consider the very important chemical reactions governing the various operations. For descriptions of these the reader is referred to works within the field of industrial chemistry.

SUGAR-MILLS are machines for expressing the juice from the cane. They usually consist of heavy rollers, driven by animal-, water-, or steam-power, through which the cane is passed. In the best-constructed sugar-mills much depends upon the adjustment of the distances of the rolls. A too close approximation causes, on the one hand, an increased expenditure of force in the working of the mill; on the other hand, if the rollers be placed too far apart, a portion of the juice escapes extraction and is carried off in the cane-trash.

The construction of a large three-roll sugar-mill is shown in Fig. 4062. The crushing rolls are strong cast-iron cylinders mounted between the two massive cheek-pieces or side-frames *B B*, and so

set that the perimeter of the upper roll is nearly in contact with the two lower ones. These rolls are very firmly keyed on a wrought-iron axial shaft, carrying at one extremity the gear-wheels by which the rolls are revolved. The shaft of the upper roll is made of increased strength, as it has to sustain simultaneously the strain of the two lower ones. The feed and delivery rolls—that is, the front and back ones—have flanges at their ends, between which the top roll is placed. These flanges are for the purpose of preventing the pressed canes from working into the mill-bed. The cheeks *B* are bolted to the bed *C*, which at the same time is so formed as to receive the inclined pans *D*, placed to catch the juice from the rolls. The whole mill is bolted to a hard-wood framing, which is supported on a stone foundation. The cheeks *B* are formed with pockets for the purpose of receiving the bearings of the shafts *E E*. Means are provided for guiding the bearings laterally, also to regulate the distance of the rollers from each other and to compensate for wear. The upper roll revolves in brass bearings surmounted by massive caps *I*, which are retained in their places by strong bolts *K*, which, traveling the whole height of the cheeks, are secured under the bed-plate by means of cotters or wedges; these bolts serve likewise, by means of the top nuts, to regulate the space between the perimeters of the rolls. Between the lower rolls is placed the returning knife, which is a concave wrought or cast plate secured to a beam of wood, arranged to project into the openings in the cheek, whereby they may be elevated or depressed by means of a screw or wedge. This return directs the cane which has been crushed between the top and feed rolls to the top and delivery rolls.

Fig. 4063 represents a so-called "Cuba mill," as constructed by Messrs. George L. Squier & Bro. of Buffalo, N. Y. This form of mill is of the largest size, the rollers being 22 by 36 in. and the weight of the entire machine 28,000 lbs. The relative proportions of a smaller apparatus of this class are shown by the following figures, referring to a "Mammoth" mill by the same makers. The top roller is 24 in. in diameter, 30 in. long on its working face, weighs 2,630 lbs., and has a steam-forged wrought-iron shaft, 6 in. in diameter, running in brass boxes. The housings are 8 in. thick, and weigh 1,650 lbs. each. The bed-plate is cast in one solid piece, and weighs 1,426 lbs. The back gear is 8 ft. in diameter, and weighs 1,650 lbs. Eight wrought-iron stay-bolts, 2 and 2¼ in. in diameter, are so arranged as to bear the main strain of the rollers. The whole mill, without feed-table or other attachments, weighs over 15,000 lbs. The peculiar features of the Squier mills are the rubber springs and wrought-iron stay-bolts. By means of the springs the rollers are, it is claimed, made self-adjusting. By nuts and screws the springs can be tightened so as to give any degree of elasticity; so that the greater the amount of cane passing through the rollers, the greater will be the pressure. The springs are thus claimed to insure even grinding of the cane, to prevent clogging or breaking from over-feeding, to facilitate feeding by rendering it easier to feed large and small canes together, and to make the mill run easier and steadier. The wrought-iron stay-bolts take the straining pressure of the rollers, in connection with the rubber springs. In this respect, an important advantage is claimed for mills thus constructed over those in which the strain is thrown upon parts made of cast iron.

4003.

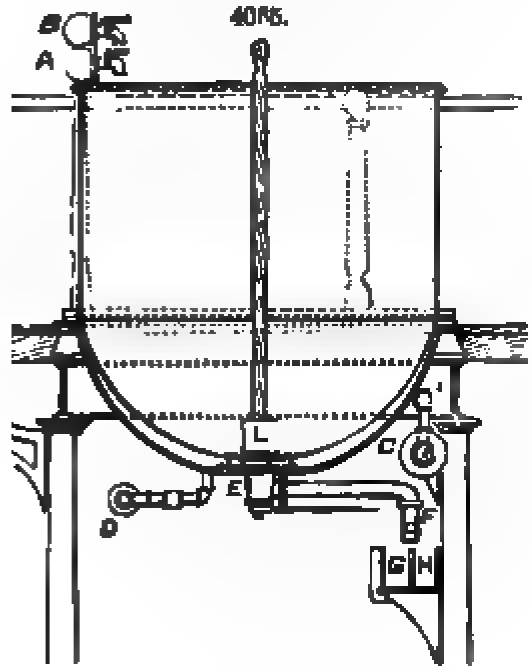
SQUIRE'S CUBA SUGAR-MILL.

Fig. 4064 represents a three-roll, self-adjusting, vertical mill by the makers above named, designed for operation by animal-power, a sweep being placed in the socket *A*. This form of mill is adapted for grinding the largest tropical cane, and is provided with the rubber springs, wrought-iron stay-bolts, and means of adjustment noted in connection with the larger mill above described.

4064.

The yield of sugar-cane mills largely depends upon the power used to drive them. It has been determined that with wind-power, utilized through wind-mills, the result is on an average but 50 per

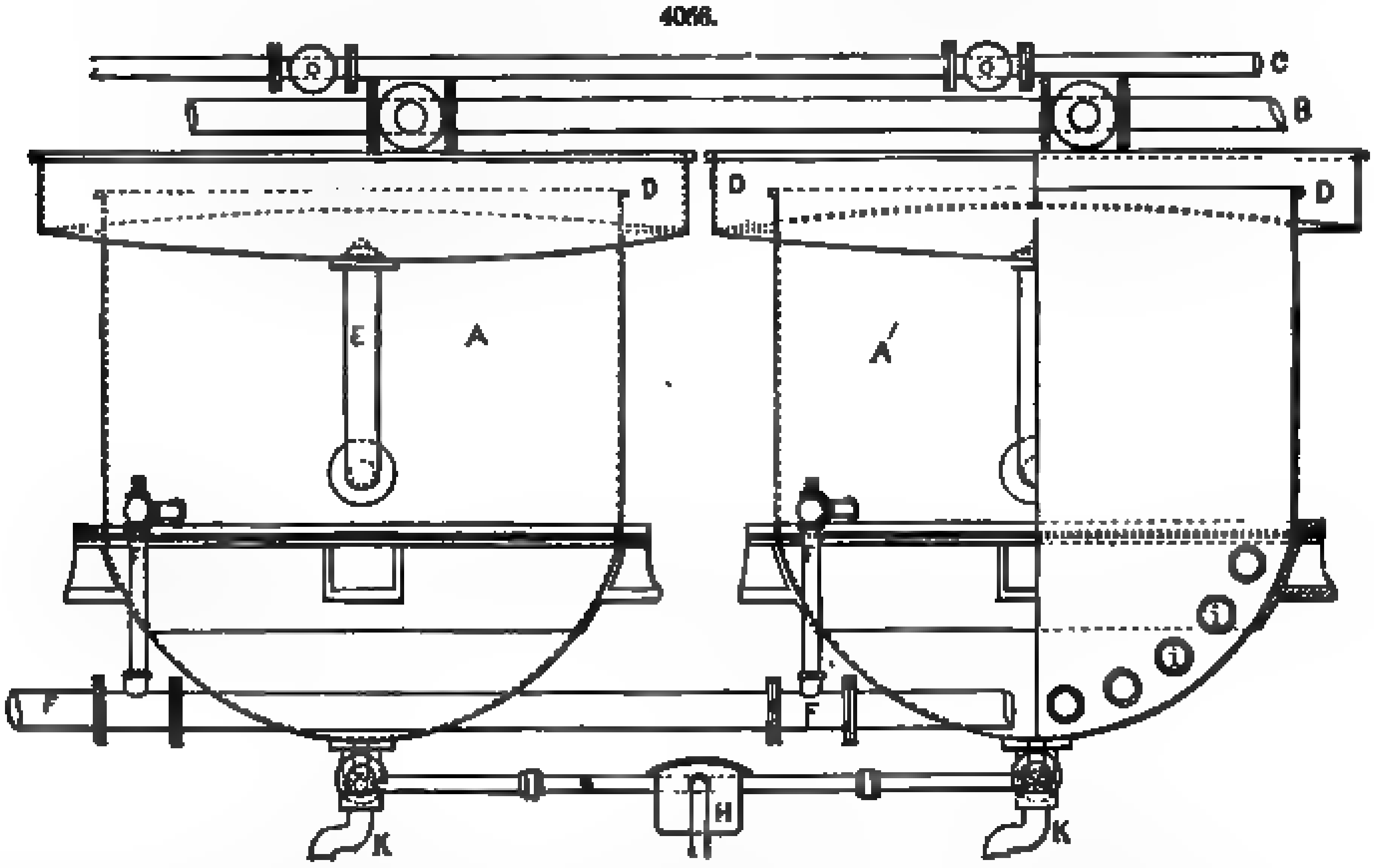
4065.



cent.; with animal power, 58.5 per cent.; with water-power, 60.8 per cent.; and with steam-power, 61.9 to 81 per cent.

Defecation and Condensation.—The juice caught in the pan beneath the mill is conducted through strainers to a tank, whence it is pumped to the defecators, or to a receiving vat from which the latter are supplied. A large number of defecating and concentrating systems have been devised, mainly with the object of saving time and fuel. The defecation of juice is produced by heat, which coagulates the albumen, and by the addition of lime, which neutralizes

4066.



the acid and renders some of the solid impurities insoluble. The heat is usually obtained from the products of combustion from under the kettles of the "Jamaica train" hereafter described, or from exhaust steam. The ordinary defecator is an oblong iron or copper tank holding some 600 gallons.

Into the top of this the juice is led by a pipe. A water-conduit is also supplied. Underneath the tank are outlet-cocks and two troughs, one serving to convey the clear liquor to the Jamaica train, and the other to convey the scum to a suitable tank.

For raw sugar defecation only takes place. For vacu
the defecating process is followed by a clarification. In
shown a sectional elevation of Colwell's round defecator
from the mill is conducted to the tanks by the cock *A*. T
heated by low-pressure steam admitted by the pipes *C*. Th
is drawn off through the strainer *E*. The nozzle *F* swings a
the stream of clear liquor into the trough *G*. The foul
liquor is directed into the trough *H*, the water-cock *B* being

An elevation of the Colwell clarifier is shown in Fig. 406
the tanks, *B* is the sirup-pipe, and *C* the pipe for the wash-
a scum receptacle. *F* is an inlet for the live steam, whic
worm in the bottom of the tank, as shown in section at *i i*.
for conducting the condensed steam to the trap *H*. *E* is
for the sirup, which may boil over into the receptacle *D*;
the outlets for the liquor

EVAPORATION is conducted either by the open-pan or the
process, according to the grade of sugar to be produced.

The Open-Pan Process.—The *Jamaica train*, to which th
after leaving the defecator, is one of the oldest and most ef
of open-pan apparatus. It consists of a row of copper or
set in brickwork. The furnace is placed under the smalle
end, and is conducted around the kettles to the chimney.
tops of the kettles is a trough for catching the scum. The
of a Jamaica train is shown in vertical and transverse se
4067 and 4068. The kettles vary in diameter from 4 to 8
est being placed as shown directly over the fire. At 1
"grand" or receiving kettle, into which the juice is fi
Here the proper dose of milk of lime, or "temper" as it
added. From this kettle the juice is dipped up and pas
No. 2, where the concentration begins, scum being rapidl
and skimmed off by the attendants. When the juice is
sirup, it is pumped or ladled into kettle No. 3; and lastly i
tle No. 4, or the battery, where it is boiled to proper densit
"teache" is by some authorities applied to all these kettl
it is restricted to the last and smallest kettle of the series.
ping teache" is a small vessel having a valve at the bot
worked by a handle. It is lowered down by means of a
teache, and the valve being opened it withdraws at once
which is then transferred to the coolers, in which granulatin
Coolers are of wood with thick sides, about 7 ft. in length
width, and not less than a foot deep. This depth and th
are requisite to secure slow cooling, without which the grains could not be coarse. In about 24 hours the graining takes place, the crystals forming a soft mass in the midst of the liquid portion or molasses. The separation of the two products is effected by drainage in what is called the curing house. This is a large building covering an open reservoir. Frames are provided for hogsheads, so that the drippings from these shall flow into the reservoir. In the bottom of each hogshead several holes are bored, and into each hole is put a crushed cane or the stalk of a plantain leaf, the lower end projecting several inches below the bottom. The hogsheads being filled with the soft sugary mixture, the molasses gradually drains away from it, dripping from the stalks. The operation goes on for three to six weeks, till the sugar is considered sufficiently dry for shipping. It still retains considerable molasses, and in the moist hold of the ship the separation continues, the molasses leaking away and involving a serious loss. The "Julius Robert diffusion process" for extracting sugar from cane is in use at the sugar establishment of Messrs. Koch, in Bayou Lafourche, Louisiana. A series of tall cylinders connected by pipes are filled with thinly-sliced canes and water. The diffusion allows the hydraulic pressure to carry off the dissolved sugar. The water is heated by steam to about 190° by a boiler through which the diffusion juice passes. It is said that a much greater proportion of the sugar is extracted by this method, and that the clarifying process is much simplified and abridged.

The Vacuum-Pan Process.—*The Rillieux Apparatus* for boiling sugar *in vacuo* is represented in

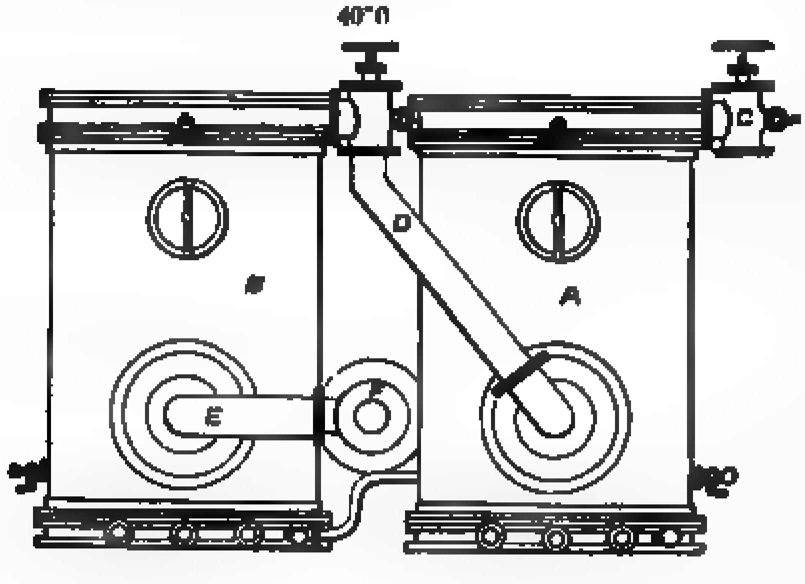
Fig. 4069, and is the invention of Mr. Norbert Rillieux of New Orleans. To heat the first pan, the escape steam from the mill engine is used, and an air-pump produces the necessary vacuum. The juice, after having been clarified and filtered, is pumped into pan *A*, from which it passes by the pipe *c* into the back of pan *B*. Thence it is conducted by the pipe *c'* to the pan *C*, and from this pan it is pumped to the clarifiers. Here the now concentrated sirup is heated and skimmed. It then passes to the bone-black filters *G*, whence it goes to a vat from which the fourth or "strike" pan *D* is supplied. The vapor arising from the juice in pan *A* supplies heat both to the pan *B* and to the strike-pan *D*. The vapor from *B* passes through the column *n* and steam-chest *F*, and up through the column *o* to boil the pan *C*. The vapor from *C* and *D* is taken to a condenser, where it is condensed by a jet of water. The waste-water from *A* is pumped back to the boilers; that from *B*, *C*, and *D* is pumped to a vat, from which it is drawn for all the cleansings of the establishment.

Figs. 4070, 4071, and 4072 represent an improved "double-effect" apparatus on the Rillieux plan. *A* and *B* are the evaporators, and *C* is the first steam-inlet valve to the drum. The vapor ari.ing in this drum passes through the pipe *D* into the rear chamber at the end of *B*, and thence into the tubes shown in section in Fig. 4072. The vapor passes to the condenser *F* by the pipe *E*. *H* is the liquor-pipe connecting the two pans.

Fig. 4073 shows the internal construction of an ordinary "triple-effect" pan. *a* is a plate of brass or composition secured to the circle and carrying the upright tubes through which the liquor passes. The steam for heating the liquor enters the drum and surrounds the tubes.

The Colwell Apparatus, made by the Colwell Iron Works of New York, is represented in Fig. 4074. *A* is the feed-pump; *AA*, bottom feed-pipes; *F*, live-steam pipe, leading into steam-drums; *D*, exhaust-steam pipe from receiver *P*, and connected with valves *E*; *FF*, overflow from air-cylinder; *G*, overflows; *H*, condensation-escape from first pan; *K*, condenser; *L*, cold-water pipe and valve for condenser; *M*, air-cylinder of vacuum-pump; *N*, connection between air-cylinder and condenser; *O*, supplementary condenser for second and third pans; *P*, receiver; *Q*, liquor-pipe from all pans to the mont-jus *C*; *S*, pipe connecting mont-jus and condenser; *X*, cold-water pipe to supplementary condenser; *Y*, return from second drum to supplementary condenser; *I*, return from third drum to same; *C*, mont-jus; *U*,

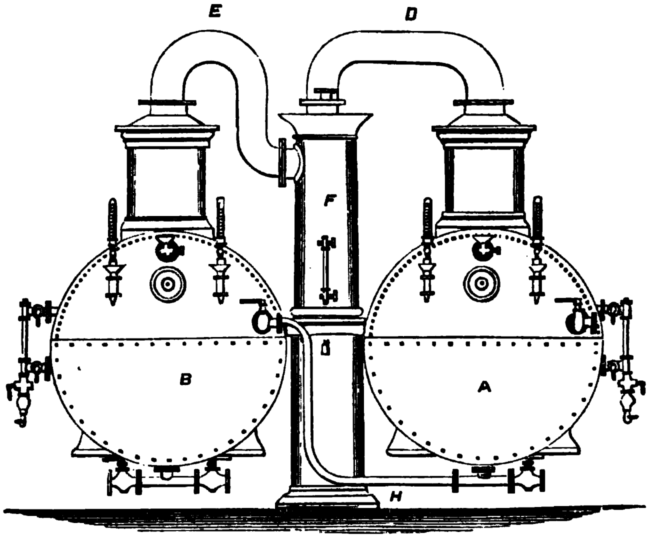
4070



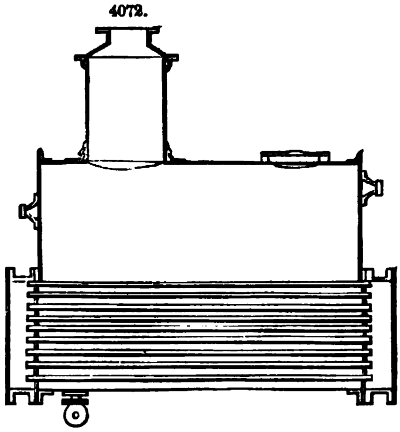
live-steam pipe for vacuum-pump; *EE*, overflow from water-cylinder; *W*, section of copper drum. The drums are composed of copper curbs having composition brass heads, into which are expanded copper tubes. When required to be cleaned, the joints on two pipes are broken, and the drum is lowered down and replaced with a spare drum, the foul drum being cleaned at leisure. During this process the operation of the other two pans need not be stopped, as the construction admits of the pans being worked at option as either a single, double, or triple effect.

The course of the liquor is as follows: The pump *A* draws the liquor from the deposit tanks, the speed being so regulated as to keep the liquor in the first pan at a certain level with a vacuum of about 5 in. of mercury, and at a temperature of about 160°. Here it is evaporated to about 15° or 16° Baumé, and is then conducted to the second pan, where the same level of liquor is maintained, the vacuum being at about 12 or 15 in. and the heat at 135° to 140°. It is evaporated to 20° or 22° B., and conducted to the third or finishing pan, where the best vacuum and lowest degree of heat are maintained. Here it is reduced to a density of from 25° to 28° B. The juice is then led to the mont-jus *C*, which is connected to the condenser and with the clarifiers. It also has a steam-pipe, steam-gauge, and safety-valve. By opening the valve and connecting the mont-jus with the condenser, a vacuum is formed equal to that in the third pan, and by opening the valve connecting it with the pan it receives a charge of liquor. These valves are then closed and the steam-valve is opened, when the liquor is forced up to the tanks that supply the clarifiers. By this means the vacuum in the third pan is not impaired, and hence the whole apparatus is kept in continuous operation. Each pan is connected with the exhaust-steam pipe *D* through the valves *E E E*, which are attached to the vapor-pipes from the overflows. Each pan also has a live-steam connection to insure against accident and give ample heating capacity. The first pan receives its heat through the valve *E*, and the vapor from the first pan passes through

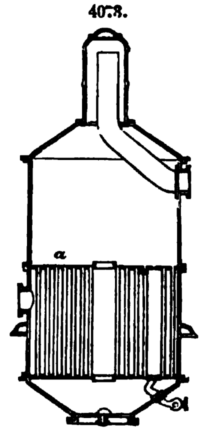
4071.



4072.



4073.



the overflow *G* and into the drum of the second pan, which acts as the condenser for the first pan. The condensation is run through a trap, or it may be conducted direct to the condenser. The vapor generated in the second pan passes through its overflow and valves to the drum of the third pan, or direct to the condenser, while the vapor generated in the third pan passes through its own overflow to the condenser. The condenser has an injection-pipe, and is also connected at the bottom with the air-cylinder of the combined air- and water-pump. The condensation of the second and third drums is connected with the supplementary condenser, the latter being connected with the water-cylinder of the pump.

SUGAR-REFINING.

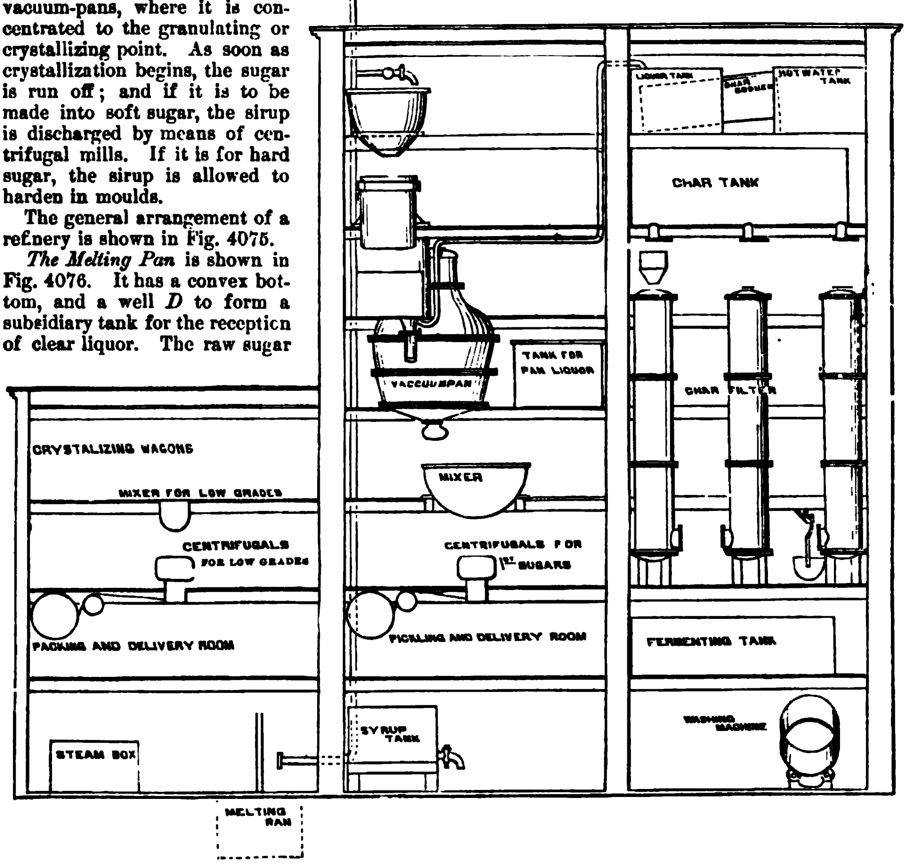
The process of sugar-refining, as carried on in most large establishments in this country, is substantially as follows: On the ground floor the raw sugar is dissolved in hot water in large cisterns. Thence it is drawn off through strainers and pumped to the top story of the building, into vessels called blow-up pans, because steam was formerly blown into them to heat them. They are now

heated to about 208° or 210° F. In these pans milk of lime is added to the liquor to neutralize any acid, and it is then conducted to bag-filters on the lower floor. From the bag-filters the sirup is run through filters of animal charcoal or bone-black, and is pumped to vacuum-pans, where it is concentrated to the granulating or crystallizing point. As soon as crystallization begins, the sugar is run off; and if it is to be made into soft sugar, the sirup is discharged by means of centrifugal mills. If it is for hard sugar, the sirup is allowed to harden in moulds.

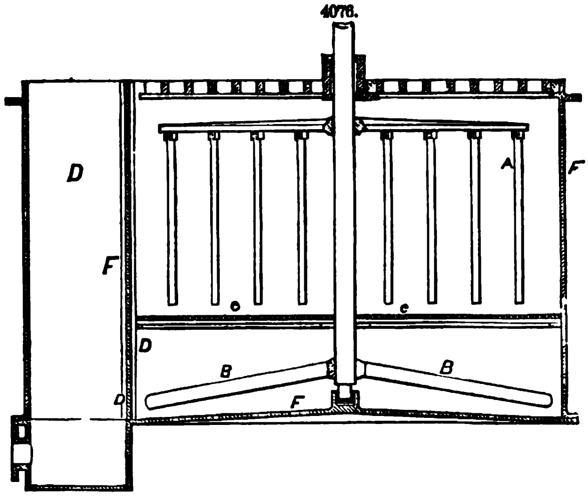
The general arrangement of a refinery is shown in Fig. 4075.

The Melting Pan is shown in Fig. 4076. It has a convex bottom, and a well *D* to form a subsidiary tank for the reception of clear liquor. The raw sugar is dumped upon the grating above, the lumps being broken and mixed with the water in the pan by means of the rams *A*. After passing through the strainer *C* the sugar is kept from settling by the propeller-blade *B*, and afterward finds its way to the well through the strainer *E*. *F* is the cast-iron curb.

4075.



4076.



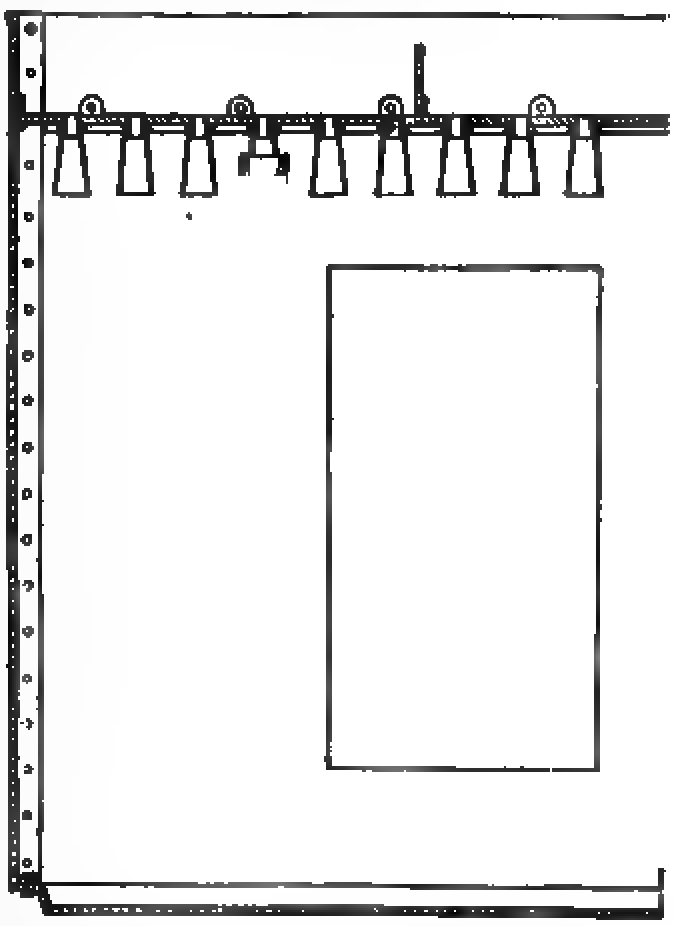
The Blow-up resembles the defecator used on plantations, but has a single bottom and is much larger. Its capacity is usually from 800 to 1,500 gallons. It is heated by a worm and live steam.

The Bag-Filters, Fig. 4077, are large iron boxes divided into sections, each section containing two rows of bags, which are inserted through doors in the sides. The bags are held by nipples screwed into the top plates of the boxes, and are so arranged that if a part of them require removal this may be done without stopping the operation of the others. The bags are double, the inner one being 40 in. and the outer 12 in. in circumference, so that the inner bag lies in folds, and thus presents a large straining area. Steam is admitted to the box to warm the liquor suf-

ficiently to cause it to run freely. After the bags become choked with impurities, the contents of the filters are emptied into a tank, and the bags are washed and returned. The refuse is pressed, the sweet liquor going to the mixing pan, and the solid remainder is sold as manure.

The Charcoal-Filters receive the liquor from the bag-filters, the same being collected in a large tank. The filter-cylinders are of iron, and are usually 10 ft. in diameter and 18 ft. high. It was formerly the practice to make their height equal to six times their diameter. The cylinder is filled with animal charcoal, and the liquor is let in. When one filter is filled, its bottom cock is opened, and the liquor is conducted to the top of another filter, and thus through all the filters successively. If after passing these filters the color of the liquor is unsatisfactory—that is, not pure and white—the filters are washed out by admitting hot water at the top, and then allowed to drain until they do not drip. Sometimes steam is used, or an exhauster is applied to the bottom to draw off the water, air following to fill up the vacuum. The lower man-hole is then opened, and the spent charcoal is conveyed to the kilns by means of a suspended rail-car. The apparatus for and mode of revivifying the charcoal is described farther on.

4077.



Vacuum-Pans.—There are two forms of this apparatus: that in which the vacuum is produced by a spray-condenser, and that in which the vapor is exhausted by a separate vacuum-pump, the water of condensation escaping through the barometric column. The former is constructed on the wet system and the latter on the dry system. A wet-system pan constructed by Messrs. Colwell & Bro. of New York is represented in Fig. 4078. The material most commonly used is cast iron. The pan consists of a bottom with lugs for supports, a curb in one or two pieces, a dome, a crown, vapor-pipe, overflow, and condenser. If the pan is worked on the wet system, the condenser can be placed close beside it; if on the dry system, it must have at least 35 ft. of waste-water or "leg" pipe, so as to counterbalance the pressure of the atmosphere. This is called the "barometric column." As this method requires the most water, the wet system is chiefly used on plantations, as the pump will act as a condenser and expel the air, it being especially constructed for that purpose. The heating surface is of seamless drawn copper tubes in serpentine coils, inclining to the centre. The bottom worm follows the dip of the bottom, and the top worm has about 4 in. dip, enough to allow for run of condensation; while the intermediate worms are arranged between with graduated dips. The worms take steam from the outside, and the water of condensation is taken out through the bottom into traps. The diameter of the worm depends upon the size of the pan. The worms are secured to cast-iron braces by a cup and caps which securely hold them from jumping during the boiling, yet allow them to expand and contract without straining the bracing or chafing the worms. Eye-glasses are provided in the dome or curb, so that the boiling action may be observed; and vacuum-gauges are also applied. The lower draw-off valve is 16 in. in diameter.

When a pan is to be charged, it is first filled with steam in order to expel the air. Water is then let into the condenser, and the vacuum-pump started. A vacuum is soon produced sufficient to draw in the liquor. When the first worm is covered, the steam is turned on and boiling is started. The quantity taken in at a charge depends upon the kind of sugar required. If a small-grain sugar is desired, charges can be frequent and copious. On the other hand, to produce a large grain, care must be exercised; for after the first charge is grained, no new grain should be allowed to form. If it is intended to purge the sugar cold, it is run into coolers, whence it is dug and conducted to the centrifugal machines. If the purging is to be done hot, the wagon is run direct to the mixer, and the centrifugal machines go to work immediately. The sugar is soon purged, cooled, boxed, and ready for the market.

Centrifugal Machines, as above noted, are used for the draining of sugar. The construction of an improved machine manufactured by Messrs. Lafferty of Gloucester City, N. J., is shown in Fig. 4079. It consists of a casing in which is a corrugated drum or basket attached to and supported by an upright steel spindle. This spindle passes through the casing, and as it rests upon the step and the step upon the lever, if the lever is lowered both spindle and basket are caused to descend, thus bringing the V-shaped brake on the bottom of the basket into contact with the wood friction inserted in the casing; and by this means the revolution of the machine is easily arrested. In order to start the apparatus, the lever is raised, thus lifting the basket and freeing the brake. The friction-cone then comes in contact with the friction-pulley, and motion is at once communicated to the spindle. The speed of the machine is from 800 to 900 revolutions per minute. The quantity of sugar purged by a machine of this class varies with the quality. Its maximum yield is with firsts (A), washed a little; the weight of a charge varying from 125 to 150 lbs., the time of a charge from 3 to 5 minutes, and the product ranging from 1,500 to 3,000 lbs. per hour.

Loaf-Sugar Cutting Machines.—In the manufacture of loaf sugar, the sirup from the vacuum-pan

4080.

as they emerge from the jaws, by revolving cutter-heads $F F$, moving, as regards their contiguous surfaces, in the same direction and in line with the feed. These cutter-heads may be of any desired shape in their transverse section, and may carry any number of cutters. The cutters $G G$ are tangentially arranged in relation with their heads, and so that they cut back of the centres of the latter close to the elastic jaws $E E$. In this way or by these means the sticks are nipped into cubes or blocks in a regular and easy manner.

4081.

The Char-House is considered a vital department in the economy of a refinery, as it is here that the spent charcoal from the filters is revivified and made again fit for use. In Figs. 4082, 4083, and 4084 is shown the combination of Colwell's drier and the Gondolfo kiln and sectional cooler, which is in general use. Fig. 4082 is a half front view; Fig. 4083, a sectional view of the kiln, and a section of the drier; and Fig. 4084, a middle elevation of the kiln through the ash-pit, and partial sectional view of the drier. Beginning with the drier, A is a rectangular box or chamber, forming a receptacle for the wet char. B is a hot-air flue leading from the kilns below. $C C$ are pipes leading through the chamber A from the flue B to the flue D, which carries the hot air and gases to the chimney, or out to the open air. The pipes C are of the form shown in the cross-section, Fig. 4083. They have a round or oval form on top, and a flat bottom. At the sides, flanges reach down below the bottom of the tube, so as to form a channel on the under side below the flat bottom. $E E$ are short tubes, flat on the top and curved upon the bottom, reaching across the flue B from the air outside the apparatus

4082. 4083. 4084.

to the channel under the tubes C. They are entirely inclosed through the flue B. $F F$ are similar tubes passing across the flue D. They connect the groove or channel under the tubes C with the upward flues G. The bottom of the chamber A is formed of two inclines, $a a$, sloping toward the sides, and forming channels, at the bottom of which are the discharge-openings $o o$. These lead by suitable pipes to the kilns, where the char is reburned.

The operation is as follows: The wet char is placed in the chamber A, through which it descends as it becomes dry, and is drawn off through the openings $o o$. In descending, the char comes in con-

tact with the pipes C, by which it is heated. It then passes down the sides, and partially around and under the lips of each pipe C, so as to leave a channel or hollow under the tube between the downward-projecting ribs. Through the opening thus made fresh air passes by means of the short tubes E and F, and the flues G. This carries off the moisture from the heated char and dries it. The char is first heated by the hot air from the kilns passing through the pipes C, and is then exposed while so heated to the current of air acting directly upon its surface in the channels under the pipes, so that it is dried as rapidly and thoroughly as possible. For the purpose of getting at the flues for cleaning or repairing, the face of the apparatus is made with removable gates, as shown at $i\,i$ in Fig. 4083. The gates over the other openings are supposed to be removed. The char leaves the drier at a temperature of almost 200° F., so that after a few minutes' exposure to the air it is quite dry on the surface. It is received into bin K, which is directly over the top of the retorts; and as the char is drawn from the coolers the retorts are charged automatically. The ordinary kiln is of cast iron. The retorts are of an oval pattern, and are set 12 on each side of the fireplace, which is about 18 in. wide and 8 ft. long. The retorts are entirely surrounded by a fire-brick wall, outside of which are the flues into which the gases escape through small outlets behind each retort after it has done its work. In this case the fire has to revivify through 4 inches of char. With the Gondolfo kiln, however, there are no flues in the walls, the products of combustion being admitted into the inner pipe or flue, which together with the outer pipe is set in the double socket so formed that, after the heated gas has done its work upon the outside pipe, it performs a further duty in its upward passage to the flue under the drier. The annular space between these two pipes is about 2 in. The char passes into a series of seven small coolers.

In Fig. 4083 is shown the Gondolfo kiln. The bottom plates O are pierced for the sockets M, and bolted to the party-beams P' and P, and the ash-pit girders Q and Q', which are in turn supported by the columns. The double sockets M are for the reception of the outside retort G and the inside one H. Openings R are provided to admit the heated gases into the inner retort.

Beet-Sugar Manufacture.

The processes of manufacture of sugar from the beet-root are as follows: The beets, having been gathered from the ground and deprived of their tops, are carted to the storing place or into the washing room of the factory, each load being accurately weighed as it is brought in. Here they are fed into the washing apparatus, which cleanses them from all adhering dirt, and delivers them to the elevator. The elevator raises them into the hopper of the rasping machine. This machine reduces them to a fine pulp or to thin slices, according to the method which is used in the factory for extracting the juice.

The methods of extraction are four in number, as follows: 1. By hydraulic presses; 2. By centrifugal machines; 3. Schützenbach's maceration process; 4. Robert's diffusion process.

The Extraction by Hydraulic Presses is the oldest process practised. It requires the most manual labor and considerable motive power. There is also considerable expense attached to it, on account of the destruction of the press-cloths, or sacks, in which the pulp is held while being subjected to the pressure. Great care is also necessary in washing the press-cloths so as to prevent fermentation.

The Process by Centrifugal Machines is much cleaner, and requires less manual labor, although considerable motive power is necessary for giving motion to the machines. A satisfactory result in this process depends almost wholly upon the proper use of water in the machines. It is absolutely necessary that just the right quantity should be used at the proper time, in order to get the best percentage of the juice from the pulp, in the most concentrated state.

Schützenbach's Maceration Process requires but very little power and less manual labor than the process by centrifugal machines. The labor, however, must be intelligent in order to secure perfect and thorough maceration of the pulp. In this process, the maceration is almost too thorough when it extracts the largest percentage of saccharine from the beets, since the substance of the beets is decomposed and much of it is carried off in the juice. This causes so much impurity as to seriously retard the crystallization of the sugar. The refuse pulp contains so much water that the use of either presses or centrifugal machines is necessary to make it fit food for cattle.

Robert's Diffusion Process is now acknowledged to be the most economical of any, both in first cost and in working. The beet-roots are cut into small thin slices and put into a chamber, in the centre of which is a cylinder containing a feeding screw, driven by gearing from above. The sliced beet-root is passed through a hopper to the bottom of the feeding chamber, whence it passes out through openings into the outer cylinder or diffuser, and, gradually rising to the top, is carried off by a regulating rake, driven by independent gearing. From the top of the diffuser water is slowly supplied through small pipes, meeting in its descent the most exhausted of the slices as they rise to the discharge level, and passing through to the richer material as it becomes more and more saturated. At the bottom it issues through perforations or outlet-pipes, and is carried off to a cistern, where it is heated, and is then returned upon the beet by the central feeding tube, by which the beet is supplied to the diffusing chamber.

Carbonatation consists in the saturation of the defecated beet-juice with carbonic-acid gas. The carbonatation pans, in which the defecated and scum juices are treated, are furnished at the bottom with a pipe pierced with three parallel rows of small holes, one-eighth of an inch in diameter, through which the carbonic acid is forced into the liquid. There are also coil-pipes or double bottoms, for heating by steam while the process is going on. When "foaming" has ceased, the carbonated juice is drawn off into large receivers or settling tanks, where it is allowed to settle, after which the juice is ready for the filters, unless, as is often done, it is subjected to a second carbonatation. The defecated and carbonatated juice, after being drawn from the pans into the mont-jus, is forced to the tanks over the charcoal filters, while the scums are subjected to the action of the filter-press in order to extract the saccharine juice which they hold. After having once passed through the filters, the juice is conveyed into the evaporators, which concentrate it, by evaporating a portion of its water, into

sirup of 24° or 28° B. At this point of concentration these sirups are passed through the charcoal filters into the vacuum-pan to be concentrated to 40° or 42° B. From the vacuum-pan the sirups are drawn into vats or "crystallizers," where the sugar is left to deposit itself in a solid form, which afterward allows of its being freed from the surrounding molasses. The complete separation of the crystals from the molasses is effected in centrifugal machines.

Works for Reference.—"Statement of the Sugar Crop made in Louisiana," Champomier (annual reports, New Orleans, 1845–'57); "Sugar-Planter's Manual," Evans, London, 1847, Philadelphia, 1848; "Practical Sugar-Planter," Wray, London, 1871; "Sugar Cultivation in Louisiana, Cuba, and the British Possessions," Leon, London, 1848; "Practical Treatise on the Cultivation of the Sugar-Cane, and the Manufacture of Sugar," Kerr, London, 1851; "Manufacture of Sugar and the Machinery Employed," Burgh, London, 1866; "History of Sugar and Sugar-Yielding Plants," Reed, London, 1866; "Treatise on the Manufacture of Sugar," Soames, London, 1872. The manufacture of beet-sugar is described by Dumas in his "Traité de Chimie appliquée aux Arts," vol. vi.; see also "De la Fabrication du Sucre de Betterave," Dureau, Paris, 1858; "Beet-Root Sugar and Cultivation of Beet," Grant, Boston, 1867; and "Manufacture of Beet-Root Sugar," Crooks, London, 1870.

SURFACE-PLATE. See PLANOMETER.

SWITCH RAILROADS. See RAILROADS, CONSTRUCTION OF.

TALKING MACHINE. See PHONOGRAPH.

TAN-BURNING FURNACE. See BOILERS, STEAM.

TAPPING MACHINE. See SCREW-MAKING MACHINES.

TAPS. See SCREW THREADING TAPS AND DIES.

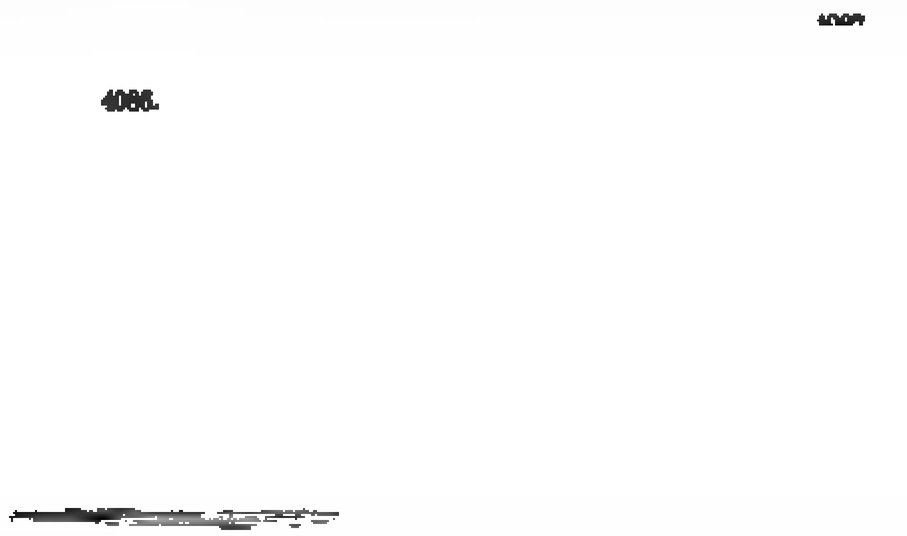
TEDDER. See AGRICULTURAL MACHINERY.

TELEGRAPH. The different systems of telegraphy in practical use depend upon electro-magnetism or chemical action. (For pneumatic telegraph, see PNEUMATIC DISPATCH.) In this country the telegraph devised by Morse and Henry is chiefly employed, the apparatus being actuated by electro-magnetism. The principal instruments in this system are the following:

The Transmitter or Key, Fig. 4086, serves to connect and disconnect the circuit at a given point on the line, and by so doing to transmit signals. It consists of a brass lever L, swung on pivots, and having on one end a button. When this button is pressed down two platinum wires, a and b, are brought into contact, thus closing the circuit; when the pressure is removed a spring lifts the lever, separates the wires, and breaks the circuit. When the message is sent, the operator permanently closes the circuit by springing to the left the lever S, which brings into contact the duplicate platinum wires a' and b'. The signals are formed by breaking up the continuous flow into long and short

4087

4086.



intervals or waves—the short waves by a momentary depression of the key-lever, and the long waves by a depression of longer duration. These waves, passing over the wires to the distant station, actuate the recording mechanism, making long and short indentations on a continuous strip of paper.

The Register or Recorder, Fig. 4087, consists of a train of gearing, deriving its power from a weight or coiled spring, which serves slowly to carry forward between two cylinders a continuous strip of soft paper P three-quarters of an inch in width. On the upper cylinder there is a small groove, in close proximity and opposite to which is an indenting point upon the end of the lever L, actuated by the electro-magnet M. The passage of a short wave over the line and through the coils of wire surrounding the iron cores causes the latter to become magnetic, and the iron armature A of the lever is thus attracted. The indenting point upon the other end of the lever is brought in contact with the moving strip of paper, pressing it into the groove and thus recording a dot. If a long wave is transmitted, the armature remains attracted to the cores of the magnet for a longer time, and the indenting point makes a long indentation owing to the moving of the paper when the lever is attracted. This long indentation is called a dash, and by a combination of one or more of these characters a distinctive signal is given for each letter of the alphabet. The annexed is the combination of dots and dashes forming the letters of the alphabet which is used upon the American lines, and with slight modifications upon those of all countries:

LETTERS.

A · —	E ·	I · ·	M — —	Q · · — ·	U · · —	Y · · · ·
B — · · ·	F · — ·	J — · — ·	N — ·	R · · ·	V · · · —	Z · · · ·
C · · ·	G — — ·	K — · —	O · ·	S · · ·	W · — —	& · · · ·
D — · ·	H · · · ·	L ——	P · · · · ·	T —	X · — · ·	

NUMERALS.

1 · — — — ·	3 · · · — ·	5 — — —	7 — — · ·	9 — · · —
2 · · — · ·	4 · · · · —	6 · · · · · ·	8 — · · · ·	0 ——

PUNCTUATION.

Period · · — — · ·	Interrogation — · · — ·	Quotation · — · · — · —
Comma · — · —	Exclamation — — — ·	Parenthesis — · · · —

In practice, the magnet of the recorder or register is seldom influenced by the direct action of the current upon the line, especially upon lines of considerable length, as for example that between New York and Washington. Considerable power is required to effect the indentation of the paper, and a current of sufficient strength cannot be made to pass through such an enormous length of wire except by the use of a very powerful battery. To dispense with the use of the latter, and obtain sufficient power to effect the indentation of the paper, a magnet sensitive to feeble currents is substituted for the recording instrument in the line, and the latter is placed in a secondary or local circuit containing but a few feet of wire and one or two jars of battery.

The Relay, Fig. 4068, is provided with a delicately-pivoted lever *L*, which is limited in its motion by two screws, the one on the right, *b*, being tipped with platinum, as is also the lever at *a* opposite to it. The spiral spring *S* serves to draw the lever away from the force of the magnet when the iron core ceases to attract the armature. The lever and point form part of the local circuit containing the register, and serve to stop and start the flow of electricity therein, in the same manner as the signaling key does in the main circuit as previously described. The relay is therefore nothing more than a signaling key operated by electro-magnetism instead of by the hand of the operator. If a wave is sent from the distant station, the lever of the relay is attracted, the lever and point come into contact, closing the local circuit, influencing the register magnet, and causing an indentation to be made corresponding to the length of the wave. The relay lever, performing no work and making but the slightest movement, is set in motion by a current many times loss in strength than that required to indent the paper. For the transmission of dispatches in either direction, a battery, key, relay, and register are required at each station; and any

4069.

4068.

number of stations may be included within the same circuit or line, the attention of the operator at any particular station being called by frequent repetitions upon the line of a specific signal given to that station. The use of a strip of paper for recording the signals is falling gradually into disuse in this country, the signals being generally read by the sound which the lever of the register makes in striking its upper and lower limiting stops. The paper-moving mechanism is dispensed with, and a simple electro-magnet and lever used instead. This is called a *sounder*, and is shown in Fig. 4069. The armature *A* is attracted by the electro-magnet *M*, causing the lever *L* to vibrate between the screws *S S*, which are so adjusted as to limit the vibrations. This apparatus is placed in the local circuit.

In nearly all foreign countries a modification of the Morse register is used, which consists in substituting an inking wheel for the indenting point, and recording the dots and dashes by depositing ink upon the fillet of paper. Of late years many improvements have been introduced in the Morse-Henry system, among which may be mentioned the repeater or translator for repeating the signals from one circuit or line into a second, or any number of circuits. It is impossible, as lines are at the present time constructed, to work between New York and Chicago direct; but by the ucc of repeaters a message may be transmitted from New York to San Francisco through repeaters stationed at Buffalo, Chicago, Omaha, Cheyenne, Ogden, and Salt Lake City. The principle of the repeater is the same as the action of the relay and register in a local circuit, as previously described. Upon transmitting a signal from New York, the electro-magnet at Buffalo attracts an armature and lever included in the circuit from Buffalo to Chicago. The connecting points are brought in contact, and a powerful battery stationed at Buffalo is put in communication with the Chicago wire. This causes the magnet at Chicago to attract its lever and close either a local circuit containing a sounder or another circuit extending to Omaha.

MULTIPLE TELEGRAPHY.—The greatest advance in the above-mentioned system has been made but recently in the introduction of the duplex system by Stearns, and the quadruplex by Edison. By the use of the former apparatus two distinct messages may be transmitted over a single wire in opposite directions at the same time, without interfering with each other. This is attained by arranging the apparatus at each terminal station in such a manner that the transmission of a signal from one will not affect the apparatus at that station. This is accomplished by providing the signaling magnets with double coils wound in opposite directions, so that if a current be transmitted through one coil

upon the magnet into the line, it is prevented from acting by the transmission of a current of equal strength through its extra coil into an artificial line. The effect of the current in each coil is to set up contrary magnetism, hence none is produced; but such a balance does not obtain at the other station, and therefore the signal is received. The transmission of a signal from the other station takes place in precisely the same manner.

The quadruplex system, which transmits four messages at the same time over one wire, two in one direction and two in the other, is fast replacing the duplex both in this country and in Europe. By its aid two messages are transmitted by increasing and decreasing the strength of the currents at each terminal station, and the other two by altering the direction in which the currents flow at each. At each station there are two relay magnets, one of which responds only to strong currents independent of the direction in which they flow through the circuit, while the other responds only to a change in the direction of the flow. Multiple transmission is effected in various ways, too complicated to admit of description here. They will be found considered in detail in "Electricity and the Electric Telegraph," by George B. Prescott, New York, 1877.

Type-Printing Telegraph Systems.—The first printing telegraph brought into practical use was devised by Royal E. House of Vermont in 1846. It consists of two entirely distinct parts—the transmitter or commutator, and the receiver or printing apparatus. The transmitter is a toothed contact-wheel, so arranged that when it is made to revolve the circuit is closed or broken 28 times. On the same shaft as this wheel is a cylinder, and on the cylinder are spirally placed 28 pins. The cylinder is arranged beneath a keyboard of 28 keys. When any key is depressed its detent is struck by the corresponding pin upon the cylinder in its revolution, and the motion of the latter together with that of the contact-wheel is arrested. Each key-, pin-, and wheel-contact corresponds to a letter, punctuation mark, or space. When the cylinder is turned from one letter to another, exactly such a number of contacts and interruptions are given as will bring a type-wheel in the receiving apparatus around to the same point. When the type-wheel stops, an eccentric forces a strip of paper against an ink-band, and presses it against the type-wheel with sufficient force to obtain an impression of the letter which happens to be in position. The House apparatus was quite extensively used on some lines in this country between 1849 and 1860; but it has been gradually superseded by the Phelps instrument below described.

The apparatus of this kind in most general use in France and Germany is that of Prof. Hughes of London (formerly of Kentucky). It is not used in this country. Two type-wheels are kept rotating synchronously together at each station, by means of a train of gearing provided with a governor. Connected to the mechanism is a transmitting cylinder, arranged with and controlled by a keyboard having a key for each letter of the alphabet. A printing lever, controlled by an electro-magnet placed in the main line, causes the printing of a letter upon a long fillet of paper, while the type-wheel is rapidly moving. This movement is caused by the energizing of the controlling magnet by the transmission of a single wave from the distant station at the proper time. Simultaneously with the printing of a letter, the type-wheel, by the action of the printing lever, is thrown slightly forward or backward, thus correcting at every impression any slight variation in the synchronous movement of the transmitting mechanism of the wheel.

The best apparatus of this character is that invented by Mr. G. M. Phelps, and in use upon the lines of the Western Union Telegraph. It is known as the *electro-motor telegraph*. The train of gearing is replaced by a simple but powerful electro-motor, and the defects of the Hughes apparatus are entirely eradicated, and the speed of transmission greatly increased. Like the Hughes apparatus, the transmitting device and type-wheel of the receiving instrument are caused to revolve synchronously under control of a governor, and each separate letter is printed by a single pulsation of the electric current, of a determinate and uniform length, transmitted at a determinate time; but, unlike the Hughes apparatus, the motion of the type-wheel is arrested while each letter is being printed, and it is automatically released the instant the impression has been effected. By this means a speed of transmission has been attained upon this instrument exceeding anything which has hitherto been regarded as possible.

The Hughes and Phelps apparatus are only adapted for working on long circuits. Many simple printing instruments have been devised of late years for use upon short wires operated by private parties, and for transmitting from a central station market quotations to various parts of a city, recording the same by printing upon fillets of paper. Those generally in use have a type-wheel rotated by means of a lever which is vibrated by an electro-magnet actuated by the transmission of a series of pulsations within the circuit in which it is placed. The lever causes the type-wheel to revolve by means of a pawl and ratchet-wheel step by step. When a letter is to be printed, the wheel is brought into a proper position, and another electro-magnet attracts a lever and effects the impression. The printing magnet is worked independently of the type-wheel, either by increasing the strength of the current, by a sudden cessation of the rapid impulses which reciprocate the type-wheel lever, or by changing the direction in which the current flows through the circuit. Printing instruments for private use have also been invented which work upon the magneto-electric principle, dispensing with all batteries, the currents being generated by magnetic induction set up in the act of transmitting the message; but this form of apparatus requires a constant power to be applied to generate the currents.

The needle system of Wheatstone, once exclusively used upon the English lines, is fast growing obsolete, being replaced by the American system.

The Mirror System.—The most delicate of all known telegraphic systems was invented by Sir William Thomson, and is exclusively used on long submarine cables. The signals are read by the deflections of a spot of light to the right or left of a zero point upon a scale. In the centre of a bobbin of fine insulated wire, included in the cable circuit, is placed a small thin mirror a quarter of an inch in diameter, and suspended by a single fibre of silk. To the back of the mirror is

secured a piece of thin steel highly magnetized. A beam of light from a lamp is thrown upon the mirror within the coil. This beam is reflected back to a paper scale some three feet distant, and there shows as a long, thin spot of light. The passage of a current over the cable and through the bobbin causes the magnetized spring and mirror to be deflected to the right or left according to the direction of the current, and the movement of the spot in various directions serves to give the necessary signals to form the message.

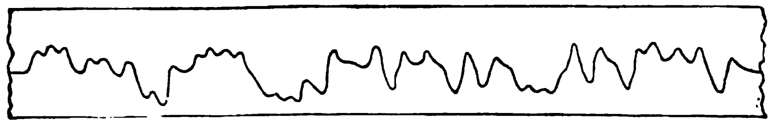
The general arrangement of apparatus is shown in Fig. 4090. In the centre of the bobbin is the circular mirror which carries the magnetized needle, rendered astatic by the magnet E fixed to a vertical rod above the galvanometer. C is the commutator of the apparatus, B the manipulator, with two keys. To the negative currents correspond the deflections of the needle and mirror to the left; to the positive currents, those to the right. F is a darkened chamber inclosing the scale on which are formed the images of the flame of the lamp situated behind it. The luminous beam passing through a hole in the side of the chamber follows the path R, falls upon the mirror, and is reflected to the zero of the divided scale, when the mirror is unmoved. At each passage of the current sent through the cable, the mirror oscillates as already described. At A is a battery of Daniell's elements, and at J the communication is made with the earth.

A modification of this instrument is the beautiful siphon recorder, also invented by Sir William Thomson. This apparatus is so arranged as actually to delineate upon paper the very irregular movements of the mirror-galvanometer needle. Fig. 4091 shows the form of siphon recorder in use upon the French Atlantic cable. The apparatus consists of a very light rectangular coil, $b\ b$, of exceedingly fine insulated wire, suspended between the poles of a large and powerful electro-magnet $N\ S$, which is charged by a local battery of large size. Within the coil is a stationary soft-iron core a, which is powerfully magnetized by induction from the poles $N\ S$. The coil $b\ b$ swings upon a vertical axis consisting of a fine wire $f\ f_1$, tl adjustable at h. The received the suspended coil, the suspensi the conductor; the coil is impell field in one direction or the oth larity and the strength of the cu it. The magnetic field in this ap and very uniform, which makes t to the weakest currents. The e fine glass tube turning upon a shorter end is immersed in the in longer end rests upon the paper is pulled backward and forward, thread k, which is attached to the swinging coil $b\ b$, and in the other by means of a retracting spring attached to an arm on the axis l, and controlled by an adjusting spindle. The paper is caused to move at a uniform rate by means of gearing driven by a small electric engine. Fig. 4092 is a facsimile of the writing of the siphon recorder, at a speed of 18 or 20 words per minute through a cable 800 miles in length. The upward waves represent dots, and the downward waves dashes. The international alphabet is here used, which is slightly different from the American alphabet. In working very long cables, the action of the current upon the swinging coil is very feeble, and the friction of the siphon against the paper strip, if allowed to come in actual contact with it, would interfere with the freedom of its movement. In such cases the point of the siphon does not actually touch the paper; the ink and the paper are oppositely electrified by an inductive machine driven by the same electric engine that moves the paper, and the electrical attraction causes the ink to be ejected from the siphon on to the paper.

4091.

THE AUTOGRAPHIC SYSTEM.—By means of this system messages may be transmitted in the handwriting of the sender, and pen-drawings may also be sent. The most successful types of apparatus

4098.



S I P H O N R E C O R D E R

are those invented by Cassells and Meyer, both of which are in use upon one or two lines in France. The Cassells apparatus consists of two large pendulums kept swinging in unison by electro-magnets placed in the line-wire. One pendulum transmits electric waves at certain intervals, which, acting upon the magnets, cause them to correct any variation from exact unison of swing. Connected to one pendulum is the transmitting and receiving apparatus. The message for transmission is written upon metallic foil with a non-conducting ink; this is laid upon a platen connected to the earth through a battery. A fine platinum wire connected to the line-wire is reciprocated from one end of the foil to the other, the foil being advanced one-hundredth of an inch after each reciprocation until the point has passed over the whole of the foil. The platinum point when passing over the foil allows the current from the battery to pass over the line. At all points, however, where it passes over the non-conducting ink with which the message is written, the current is prevented from passing into the line. At the distant station a similar point is reciprocated over a platen, upon which is laid a sheet of chemically-prepared paper; the passage of the circuit through the reciprocated point and moistened paper causes a blue mark to appear. If both pendulums are started at the same instant, the form of the metallic foil upon which the message is written will be reproduced upon the chemical paper by blue lines blending one into the other. But owing to the non-transmission of any current where the transmitting point passes over the non-conducting ink, no mark will appear; hence the message will be inscribed in white characters upon a blue ground. By an ingenious device Cassells reversed this action and caused the characters to be recorded in blue upon a white ground. The manner of preparing the message, as well as the complication of the apparatus, has prevented the general adoption of this system.

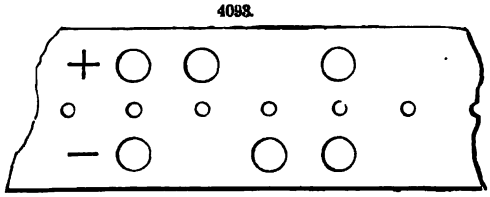
The apparatus invented by Meyer is more simple than that of Cassells. Recording by chemical action is replaced by a record with ink. At each station the synchronously-moving iron style is replaced by a rotating cylinder, a single spiral rib on which glides over the foil, on which the communication is written as before. At the receiving station an ink-roller revolves in contact with the edge of the screw-thread, and just beneath the cylinder is a band of paper which advances synchronously with the foil sheet at the sending station. At the latter the current is sent to the line as often and as long as the screw comes in contact with the non-conducting writing on the tin foil. At the receiving station the current passes through an electro-magnet, whose action raises a platen located directly under the cylinder, and the paper, pressing the latter against the inked edge of the screw-thread, thereby produces an impression.

Cowper's Writing Telegraph.—The autographic system of telegraphy explained in the foregoing paragraphs transmits a copy of the writing or sketch. By the writing telegraph devised by Mr. E. A. Cowper of London, the message is transmitted by the act of writing it. The principle of the apparatus depends on the well-known mathematical fact that the position of any point in a curve can be determined by its distance from two rectangular coördinates. It follows, then, that every position of the point of a pencil, stylus, or pen, as it forms a letter, can be determined by its distance from two fixed lines, say the adjacent edges of the paper. Moreover, it is obvious that if these distances could be transmitted by telegraph and recombined so as to give a resultant motion to a duplicate pen, a duplicate copy of the original writing would be produced. But inasmuch as the writing stylus moves continuously over the paper, the process of transmission would require to be a continuous one; that is to say, the current traversing the telegraph line, and conveying the distances in question (or what comes to the same thing, the up and down and direct sidelong ranges of the stylus) would require to vary continuously in accordance with the range to be transmitted. Mr. Cowper effects this by employing two separate telegraphic circuits, each with its own wire, battery, and sending and receiving apparatus. One of these circuits is made to transmit the up and down component writing of the pencil's motion, while the other simultaneously transmits its sidelong component. At the receiving station these two components are then recomposed by a pantograph arrangement of taut cords or levers, and the resultant motion is communicated to the duplicate pen at that place. The plan adopted by Mr. Cowper to transmit each continuously varying component is to cause the resistance of the circuit to vary very closely with the component in question. An illustrated detailed description of the apparatus appears in *Engineering*, xxvii., 180.

AUTOMATIC SYSTEMS.—In these systems the transmission and reception of the message over the wires are conducted entirely by automatic machinery. There are three in use, those of Wheatstone, Siemens-Halske, and Edison. All are based upon the same principle as that of the controlling cards of the Jacquard loom. Three essential devices are embodied: (1), the perforator or puncher, for preparing the message by perforating the characters in the strip of paper; (2), the transmitter, for causing such characters to be sent in the form of electric waves through (3) the receiver, which carries forward a strip of paper, upon which the characters are recorded either by chemical decomposition or by ink. The Wheatstone punchers consist of three keys, one for the dot, one for the dash, and one for feeding the paper forward a short distance after each letter has been perforated.

The paper is prepared at a speed of from 18 to 20 words per minute. The Siemens-Halske perforator is similar to the Wheatstone. The Edison perforator consists of a keyboard of 28 keys. The depression of a key perforates the letter entire, and feeds the paper the proper distance forward. The paper is prepared at a speed of from 35 to 50 words per minute. The Wheatstone transmitter consists of a clock movement, which sets in rapid vibration two rods, which operate by levers to open and close the electric currents, and which when the strip contains no perforations strike against the paper, and are thus limited and prevented from transmitting a wave over the wire. When a perforation occurs, the rod or rods pass upward through the hole. Having thus greater latitude of movement, they allow the circuit-closing levers to come in contact, and a wave is transmitted. The action of one rod serves to transmit a wave in one direction, while the action of the other rod serves to transmit it in another, so that the characters are sent by reversals of the direction in which the circuit flows through the line; a fact necessary with this system, owing to the peculiar arrangement of the receiving apparatus. Accurate feeding of paper is attained by using a supplementary row of holes placed at equal distances from each other, and the paper is carried forward by a toothed wheel engaging the holes. Fig. 4093 is a specimen of a perforated strip used in the Wheatstone system. The perforations which regulate the contact-making portion of the transmitting apparatus are represented by the larger circles, while the centre row of holes is represented by the smaller circles. By this row of holes the paper is carried forward on the transmitter. The slip is perforated for the letter R of the international alphabet.

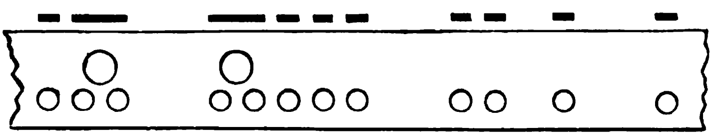
4093.



The transmitter of the Siemens-Halske system consists of a magneto-electric apparatus. The currents necessary for signals are obtained by induction, and pass over the wire alternately in one or the other direction. The transmission of the currents so generated is regulated by the groups of perforators.

In Edison's system the transmitter consists of a drum rotated by a crank connected to the battery and earth, and which serves to carry the paper forward with great rapidity. Resting on the paper is a double spring tipped with small platinum wheels. These are both connected to the line, and arranged so that they will come in contact with the drum where a hole in the paper passes under them, thus connecting the line with the battery. Fig. 4094 shows a strip perforated with Edison's apparatus. The first group of holes represents a dash, and serves to transmit a long wave. The upper perforation is used in conjunction with one wheel, to bridge over the intervals between the

4094.



two lower perforators by keeping the line in contact with the drum while the other wheel is passing the space between the two smaller holes.

The receiving apparatus employed by Wheatstone consists of a clockwork for drawing the paper forward on an electro-magnet which gives motion to an ink-wheel. The electro-magnet is polarized by having its core made permanently magnetic; hence it responds only to signals formed by reversing the direction of flow of the current through the wire A positive current, for instance, causes the polarized magnet to bring the ink-wheel out of an ink-reservoir and up to the paper, so that it continues to deposit ink upon the latter until a negative current is transmitted, which causes the magnet to attract the lever and ink-wheel away from the paper. This system is employed only in England. The highest speed is 180 words per minute on short lines. The average speed on all lines is 100 words per minute. The receiver of the Siemens-Halske system is similar to that of Wheatstone, and the speed about the same.

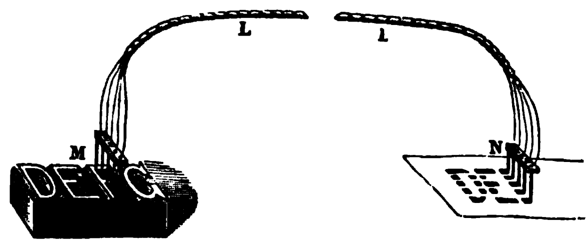
The receiver of Edison's system is an electro-chemical one, the characters being formed by the electric decomposition which takes place when a current of electricity is passed through moistened paper by means of a metallic wire resting upon it. A drum rotated by a crank serves to carry forward the moistened paper. The drum is connected to the earth. A wire resting upon the paper is connected to the line; the wire (usually brass) is tipped with metallic tellurium. When no current passes through the line, point, paper, and drum, no mark is made; but if a single wave is transmitted, the passage of the current through the moistened paper causes the decomposition of the water, setting free oxygen and hydrogen. The hydrogen combines instantly with the tellurium to form hydrotelluric acid, and almost but not quite simultaneously the acid is decomposed by the action of the air, depositing finely-divided tellurium upon the paper, and leaving a very blackish brown mark the width of the wire, and of a length equal to the length of the electric wave transmitted. The characters are recorded with extraordinary rapidity, 3,150 words having been transmitted from Washington and recorded by this means in New York in one minute; and the characters are so sharp and clearly defined that a sentence of four words can be recorded in the space of one-eighth of an inch. Another modification consists in using an iron point and moistening the paper with chloride of sodium and ferrid-cyanide of potassium. The passage of the current causes the forma-

tion of protoxide of iron on the point, and the ferrid-cyanide combines instantly with it to form Turnbull blue. The results are not equal to those of the tellurium point. An important adjunct to the system, by means of which high speed in transmission is obtained, is the use of a compensating system, whereby the retarding effect known as the static or after charge is rendered null on lines of ordinary length. The compensator consists of a series of electro-magnets contained in an artificial line at both the transmitting and receiving stations. The passage of the current through the line transmitting the signal sets up the static or after charge, while its passage on the artificial lines charges the magnets, which upon the cessation of the main circuit (the extra current from the magnet having a tendency to pass into the main line in one direction) is balanced by the tendency of the static or after charge to pass in the opposite direction. Hence, the moment the battery is disconnected from the line, the signal upon the chemical paper ceases. Were no compensation used, the characters would at high speed be so polarized as to run into each other and make a continuous unintelligible mark. This system has been in use for a number of years in this country.

Many other automatic systems have been devised, but those above mentioned are the only ones that have come into extended use.

Automatic Typo-Telegraph Systems.—In these systems Roman letters are transmitted and recorded instantaneously. The first system invented was that of Bonnells, Fig. 4095. The transmitter consists of a traveling carriage moved by power, the message being set up in type, which are connected to the battery and to earth. A comb *M*, of five points, is placed in line with the type, so that the passage of the type under the comb causes the prongs to touch all parts of the letter as they pass rapidly under it. Each prong is connected to a wire; hence five wires united in the line *L* are employed between the transmitting and receiving stations. At the distant station a similar comb *N*, of five prongs, is used, the tips being formed of platinum. These rest upon paper moistened with a solution of nitrate of manganese or iodide of potassium. The paper, which is a continuous strip, is carried forward by a train of wheels. In the transmission of the letter *I*, for instance, the five prongs at the transmitting station come in contact with the letter simultaneously; hence each wire receives a short wave, which, passing over the line and through the points upon the chemical paper, causes a decomposition of the manganese salt, leaves five dots one above the other, and thus forms the letter I. In the case of the letter T, the upper pen comes in contact with the top portion of the T at times when the other four do not touch the type. Hence the first point transmits a long wave, which is recorded by the top point at the receiving station, while no current is transmitted on the other four wires except when all the points come in contact simultaneously to form the lower part of the letter. By this system a rate of speed equal to 1,000 words per minute has been attained on short lines.

4095.



The American system devised by Edison is based upon the same general principle as that of Bonnells, but the devices are entirely different. Instead of setting up type to transmit the message, the letters are formed by groups of holes perforated in fillets of paper by a perforating machine. This machine consists of a die with 25 holes massed in a square into which 25 punches fit. Each punch is connected to a separate long thin bar. These bars are provided with pins at certain intervals, by means of which the bars necessary to form a letter are carried forward by the depression of a key. There being 28 keys in all, a single depression serves to perforate an entire letter and feed the paper forward. The average speed of perforation is from 35 to 50 words per minute, although a speed of 90 words has been attained by a very expert operator. Two wires are employed for transmitting the characters; but one-half of a letter is transmitted at once. The record is made upon chemically prepared paper, as with the Bonnells system. A speed of 1,200 words per minute has been attained with this system between New York and Philadelphia.

Acoustic Telegraph.—This system is now (1879) being developed. The principle upon which it operates is the transmission of several series of electric waves simultaneously over a single wire, by means of tuning-forks or reeds adjusted to a definite pitch or rate of vibration, and the reception and analysis of these waves by similar tuning-forks or reeds at the distant station. The most successful system is that of Gray. This consists of several reeds, each tuned to make a certain number of vibrations per second. Each reed is provided with electric contact-springs, which act to throw in and out of the line a small battery at each vibration. Each reed is also kept in continuous vibration by an electro-magnet local battery and a supplemental contact-spring. The vibrations of the reed serve to open and close the circuit of the magnet which gives it motion, in the same manner as the automatic circuit-breaker of an induction coil. A Morse key is connected with each reed, to enable the operator to stop and start the waves over the wires. The different series of waves which pass over the wires simultaneously are separated or sorted out, so to speak, at the distant station by means of reeds tuned to the same pitch as the reeds at the transmitting station. Hence, if at the transmitting station five reeds are in vibration and are transmitting their waves over the wires, the five corresponding reeds at the receiving station will be set in vibration by the action of these waves on the electro-magnet with which each reed is provided. If now, by the depression of a Morse key connected to any reed, the wave from it is prevented from passing over the line, the reed at the distant station tuned to respond only to this series will come to rest almost instantly, notwithstanding

the fact that the other waves are energizing its electro-magnet; the reason being that the reed can only be made to respond to waves which follow each other at certain definite rates, and which correspond to its proper tone. By suitably manipulating the keys connected to each reed, several messages may be transmitted simultaneously, the characters being received by the discontinuous musical sound given out by the receiving reeds when they are stopped and started. Bell, Edison, La Cour, and Varley have each acoustic systems similar in principle to that of Gray; but none have been so perfected as to come into actual use. (See TELEPHONE.)

FIRE-ALARM AND DISTRICT TELEGRAPH SYSTEMS.—These systems are employed for local telegraphing, usually in large cities. The former serves to transmit from various parts of a city to a central station a fire signal, which is retransmitted by automatic machinery to various towers containing bells controlled by electro-magnets and operated by wires connected to the central station. The district telegraph system is the same in operation and principle, and is used for connecting telegraphically a central office with private dwellings, stores, etc., to enable the owners to call to their aid either a messenger, a policeman, or the fire department. The apparatus for transmitting the signal (which is generally a number) consists of a metallic wheel provided with a number of suitably arranged teeth. The spaces between the teeth are filled with a non-conducting substance, such as ivory. Resting on the rim of the wheel is a contact-spring, which is connected to one end of the line and the wheel to the other. By means of a lever which is moved through a considerable distance by the sender of a signal, a spring is wound up sufficiently to set a train of gearing in motion and give the character-wheel several rotations. This causes the signal to be repeated over the wires many times. At the receiving station an automatic Morse register is set in motion by the first signal, and records the subsequent signals by indentations on the paper. This signal is at once seen by the operator in attendance, and is by him retransmitted to all the towers containing alarm-bells, where it is reproduced and made audible throughout the city. In the case of the district telegraph, the signaling apparatus is so arranged that when the lever is carried round for a given distance the character-wheel is caused to give one revolution, which signifies a messenger; if moved still farther to a marked point, the wheel makes two revolutions and repeats the signal, which signifies that a policeman is wanted; and if the lever is carried to its full limit, the wheel gives three revolutions, repeating the signal three times, signifying that the fire-extinguisher is required to extinguish an incipient fire.

CONSTRUCTION OF TELEGRAPH LINES.

Wire.—The best wire for telegraphic purposes is made from pure Swedish charcoal iron, and is galvanized to protect it from oxidation. The most usual sizes are No. 9, weighing 323 lbs. to the mile, and No. 8, weighing 389 lbs. to the mile. Many of the more important lines of the Western Union Telegraph Company are now built of No. 6 wire, weighing 570 lbs. per mile. In jointing, the end of each wire is closely turned around the other four or five times and then cut off short. The joint is finished by dipping in melted solder.

Poles.—In this country timber is used for poles. In Europe light iron structures or wood saturated with preservative solutions are employed, the scarcity of timber rendering economy in its use necessary. In the United States, chestnut, white and red cedar, and redwood are chiefly utilized. Chestnut and white cedar will last for 16 years; red cedar has remained unimpaired for 25 years. Poles are seldom less than 25 ft. long by 6 in. in diameter at the top. When of this size they carry from 7 to 9 wires. On important routes their length sometimes reaches 90 ft. They are usually placed about 176 ft. apart, numbering 30 to the mile. The cross-arms are of seasoned white pine, 4 by 5 in. thick, and varying in length according to the number of wires carried, usually from 3 ft. for two wires to 7 ft. 6 in. for six wires. The practice is to place all the arms on the same side of the pole, at distances of 22 in. apart between centres. Fig. 4096 is an example of the standard style of construction in the United States, the pole being arranged to carry seven wires.

4096.

Insulators.—The following, according to Prescott, are the essential qualities of a good line insulator: "The material of which it is composed must itself be possessed of high insulating qualities, and should not be subject to decay or deterioration from long-continued exposure to the weather. The surface must be repellent of moisture and not liable to retain dust or smoke. The form should be such as will interpose the greatest possible insulating surface between the line-wire and the cross-arm or pole, compatible with the necessary mechanical strength for supporting the wire. The following materials are most commonly used for insulating purposes: Glass, glass with an iron covering, vulcanized rubber, brown earthenware glazed, same in combination with vulcanized rubber, white porcelain, and baked wood prepared with some resinous compound. Fig. 4097 represents a glass insulator, provided with a screw-thread which fits upon a thread cut upon the wooden supporting-pin. By this arrangement the insulator is prevented from being drawn off the pin by an upward strain, or by the action of the wind on the wires. The mode of attaching the wire is shown in Fig. 4098. The

average percentage of glass insulators broken on the lines of the Western Union Company for a period of four years was 6.4. Fig. 4099 is an insulator of whitewood impregnated with a non-conducting compound, and arranged to hold the wire by suspension.

4097.

4099.

4098.

Underground Telegraph Lines.—A valuable report on this subject was made in 1879 to the Chicago City Council, by Mr. J. P. Barrett, superintendent of the city telegraph system, from which the following facts are taken:

"The principal portion of the telegraph wires in the leading cities of Europe are laid underground, and in the city of London there were in 1875 3,500 miles of underground wire belonging to the government telegraph system; and in Paris, about the same date, all the wires were underground. In Germany there are several underground telegraph lines, between one city and another. For instance, Berlin is connected with Hamburg, Mayence, Strasburg, Cologne, and many other cities by underground lines the entire distance. The cables contain from five to seven conductors each, insulated with gutta-percha, and the whole protected with an armor of iron wires. This system has shown itself in practice to be both economical and reliable. There are in Paris working lines that have been buried for 25 years, and which have been the cause of little or no expense. The different systems of underground wires hitherto employed are these: The larger proportion of the work which has been done has consisted of copper wire, insulated first with gutta-percha, and the gutta-percha protected from the action of the atmosphere by a covering of tar and tarred tape. The wires so protected are bunched together in a sort of cable and drawn through an iron pipe. In some cases the wires, after being insulated with gutta-percha, are protected by a series of galvanized iron wires, laid spirally around the cable. The pipes containing the wires have been generally laid in the ground at a depth of 2½ or 3 ft. below the surface. In Paris the cables are coated with a lead covering and hung in the sewers. Another method of insulating and protecting underground wires has been by the use of an insulator known as kerite, which is a form of vulcanized rubber especially adopted as a telegraph insulator; and the copper wires, after being insulated with kerite, are laid in lead or iron pipe or wooden boxes under the ground. Another method, by Professor Brooks of Philadelphia, has been successfully employed, which consists in covering the copper wire by winding or braiding with cotton thread, depriving the thread of its moisture so as to secure a high degree of insulation, bunching the wires together, as many as are required on a given route, drawing them into an iron pipe, and filling the pipe and keeping it full of specially prepared paraffine oil, which serves to keep out moisture from the pipes and to insulate the wires." In London the cost of laying 60 underground wires was £23 8s. 7*d.* per mile of wire.

SUBMARINE TELEGRAPH CABLES.—The design and construction of a submarine cable vary with the circumstances under which it is used. Near coasts where the sea is shallow and the cable is exposed to accidents from the waves, the size of the line is greatest, while in deep water the smallest diameter possible is used. The conducting wires are completely insulated from the iron envelope outside, and from each other, by layers of gutta-percha. The wires are usually of copper, and after being covered with gutta-percha they are subjected to the most careful tests for conductivity before being made into cable. Between the gutta-percha and the iron which forms the protecting envelope is placed a layer of hemp, technically termed the bedding. The conducting wires, usually seven in number, are twisted into a single strand; this is covered with the hemp bedding soaked in Stockholm tar, and outside of this is a series of galvanized iron wires twisted into spiral form. Figs. 4100, 4101, and 4102 represent the Atlantic cable from Valentia to Newfoundland, showing the various sizes at two-thirds their actual dimensions.

The laying of a submarine cable involves much special machinery. For the laying of the Atlantic cable in 1866 the Great Eastern was employed, the immense size of the vessel adapting her especially to the work. The cable itself was coiled in three circular iron tanks built on the main deck of the ship, as shown in Figs. 4103 and 4104. The largest of these tanks was 58 ft. 6 in. in diameter, and

all were of a uniform depth of 20 ft. 6 in. In these tanks the cable was coiled, the coiling beginning at the outside. In order to prevent depreciation of its gutta-percha coating and to allow of its electrical condition being effectually tested, the cables while thus stowed were kept submerged in water.

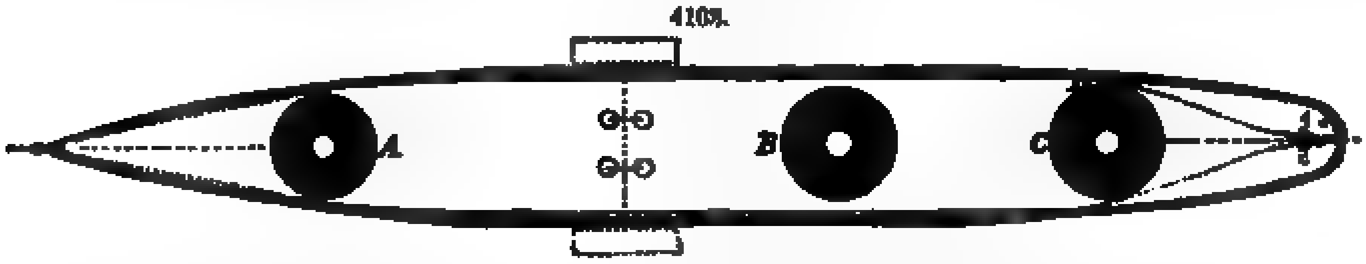
4100.

4101.

4102.

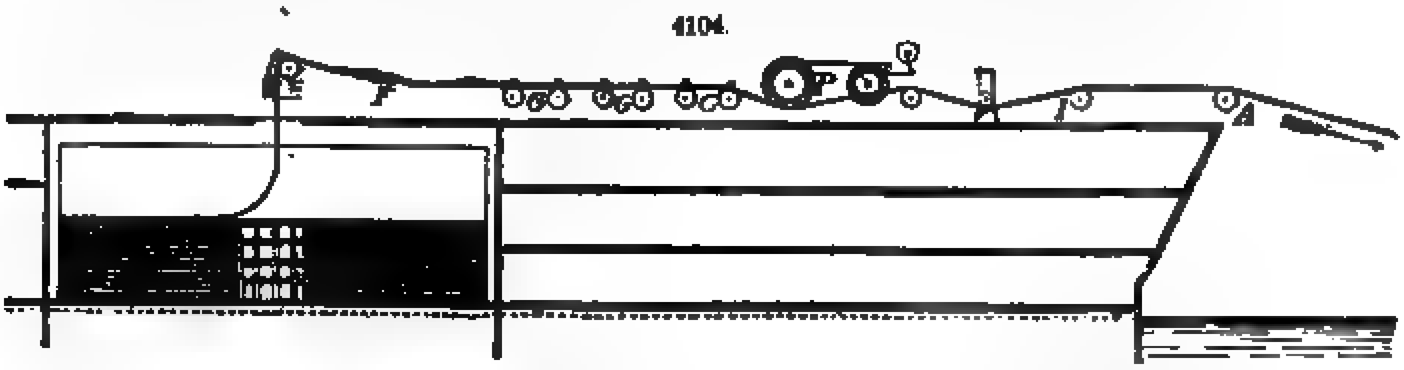
The paying-out machinery, shown in Fig. 4104, consisted of a large wheel *E*, about 4 ft. in diameter, over which the cable was passed, and then conducted through a trough *F* in which rollers were placed. In the paying-out machinery the chief object to be attained was to supply some means of checking the cable in the most regular manner possible while passing out of the ship, and also of keeping it in a state of constant tension. This tension it was necessary to regulate by the depth of the water in various parts of the ocean, and also to some extent by the speed of the ship. On entering the machinery the cable was passed over a series of six deep-grooved wheels, each about 3 ft. in diameter, shown at *G*, on the shaft of each of which was placed a friction-disk and strap; and above each grooved wheel was a jockey-wheel which pressed the cable down into the grooves. The jockey-wheels could be lifted so as to allow the cable to slip freely through the groove in the carrying-wheel. After the cable had passed through this part of the machinery, called for distinction the "jockey-gear," it was led to the main paying-out drum *P*, over which it was passed four times. On the shaft of this drum was placed the main friction-gear, an ingenious self-adjusting arrangement of Appold's brakes. The cable, having been sufficiently checked by the means described, was passed over the stern-wheel *A* into the sea, and on its way the actual strain was measured by a dynamometer placed at *D*. Immediately after leaving the drum the cable passed over two wheels, one of which is shown at *I*, and between these wheels the dynamometer was placed.

4103.



The paying-out drum was supplied with steam-power for reversing its action and picking up the cable, should any fault occur requiring such an operation. In paying out the cable, the portion in the after tank was first taken, then the fore tank was emptied, and the middle tank was left to the last, the ends of the cable from the several tanks having been spliced together in that order of con-

4104.



nection. The whole of the cable in the three tanks was spliced into one length before the paying out commenced. The total length of cable paid out was 1,851 knots, and the time from shore was 14 days, giving an average of 132 knots a day paid out, and an average rate of 5½ knots an hour for the cable. The total distance run was 1,669 knots, making the average proportion of slack paid out 11 per cent.

Works for Reference.—"Experimental Researches in Electricity," Faraday, London, 1839–'55; "Traité de la Télégraphie Électrique," Moigno, Paris, 1849; "Der Elektromagnetische Telegraph," Schellen, Brunswick, 1850–'66; "The Electric Telegraph, its History, etc.," Highton, London, 1852; "Historical Sketch of the Electric Telegraph," Jones, New York, 1852; "The Electro-magnetic Telegraph," Turnbull, Philadelphia, 1853; "Telegraph Companion," Shaffner, New York, 1854–'5; "Telegraph Manual," Shaffner, New York, 1859; "History, Theory, and Practice of the Electric

Telegraph," Prescott, Boston, 1859; "Télégraphie Électrique," Gavarret, Paris, 1852; "Electrical Accumulation and Conduction," Webb, London, 1862; "Télégraphie Électrique," Dumoncel, Paris, 1864; "History of the Atlantic Telegraph," Field, New York, 1866; "The Telegraph Cable," Griscom, Philadelphia, 1867; "The Electric Telegraph," Sabine, London, 1867; "Reports of United States Commissioners to Paris Exposition of 1867: Review of Telegraphic Apparatus," by Prof. S. F. B. Morse, Washington, 1868; "On Electrical Measurement," Clark, London, 1868; "Der Bau von Telegraphenlinien," Ludewig, Leipsic, 1870; "Hand-Book of Practical Telegraphy," Culley, New York, 1870; "Electrical Tables and Formulæ," Clark and Sabine, London, 1871; "Das Telegraphen-Recht," Meilli, Zurich, 1871; British Association's "Report on Electrical Standards," Jenkin, London, 1873; "Guide to the Electric Testing of Telegraph Cables," Hoskiœr, London, 1873; "Telegraph and Travel," Goldsmid, London, 1874; "A Manual of Telegraph Construction," Douglas, London, 1875; "Electricity and the Electric Telegraph," Prescott, New York, 1877. See also list of works cited under ELECTRICITY. T. A. E. (in part).

TELEPHONE. An apparatus for the transmission of sound, either by direct conduction of the sound-waves, or by the analysis of the vibrations producing sound at one point and their recombination at another. Telephones may be divided into two classes, acoustic and electrical. In the first, the sonorous vibrations are directly conducted; in the second, electrical impulses modified in accordance with the sonorous vibrations are transmitted. Electrical telephones are either musical or articulating. The former cannot transmit speech; the latter transmit both musical and articulate sounds.

THE ACOUSTIC OR THREAD TELEPHONE consists simply of a transmitting and a receiving box, one end of each of which is closed by a stretched membrane, and the two membranes or diaphragms are connected together by a thread or wire attached to their centres. Through this connecting thread the motion of one membrane is communicated to the other, and sound-waves may in this way be conveyed to a considerable distance and be reproduced audibly on the membrane at the other end. A series of interesting experiments on this device has been made by Mr. J. W. Miller (see paper "On the Transmission of Vocal and other Sounds by Wires," read before the British Physical Society, 1878), who succeeded in transmitting minute and delicate sounds over a distance of 150 yards through a copper wire .018 in. in diameter. To each end of the wire was attached a sheet-iron disk 3½ in. in diameter, fastened in a wooden rim about half an inch deep.

ELECTRICAL TELEPHONES.

MUSICAL TELEPHONES.—The main object sought in the invention of these instruments, which antedate the speaking telephones, was a means of transmitting musical notes electrically as a practical and useful mode of telegraphing signals. The principal devices of this kind are those of Reis, Varley, La Cour, and Gray. All of these experimenters followed the same principle by different ways. In all their systems a sounding body yielding a note is employed, the vibration of which body serves to make and break contact, giving to a current of electricity an intermittent character, the number of interruptions varying of course with the note sounded at the transmitting end; and the armature of an electro-magnet at the receiving station, adjusted to respond to those impulses, is arranged to communicate to the air the number of vibrations transmitted, and to reconvert them into sound.

Reis's Telephone was devised by Philip Reis in 1860. A membrane is stretched over a hole in a box, which has a mouth-piece. When notes are sounded into the mouth-piece, the membrane is thrown into vibration, and a platinum plate attached to its centre makes and breaks contact with a contact-screw, and in so doing completes and interrupts an electric current which traverses the receiving instrument. The latter consists of a small iron bar surrounded by a helix of wire which is in circuit with the transmitter, so that the bar or core becomes magnetized and demagnetized at each complete vibration. By this means, the note sounded into the transmitter is reproduced by the receiver, the action of the two instruments being isochronous.

Varley's Telephone was devised by Mr. Cromwell Varley in 1870. It consists of a tuning-fork or vibrating reed, in connection with an electrical condenser which transmits vibratory currents of electricity to a distant station.

La Cour's Telephone was devised by M. La Cour in 1874. A tuning-fork is used to produce interruption of the current. The fork is connected by a light key with the battery, and by a spring to the line. The key is manipulated in the ordinary manner, but the passing current is interrupted at each vibration of the fork when it breaks contact with the spring. The receiver consists of a soft-iron fork, the prongs of which are surrounded (but free to vibrate) by bobbins wound with insulated wire. Close to the projecting ends of the fork are two vertical electro-magnets. The currents from the transmitting lines pass through the coils around the fork, and thence through the other pair of electro-magnets. By this arrangement the prongs of the fork acquire polarity opposite to that of the electro-magnets, and are thrown into vibration at a rate depending upon the number of interruptions; and a note the counterpart of that transmitted is the result.

Gray's Telephone was invented by Dr. Elisha Gray in 1874. In this device a tuning-fork or reed combines both functions of sound-producer and contact-breaker. When once adjusted, it only transmits to the receiving instrument the number of pulsations of current per second due to its own note. The receiver, like that of Reis, is formed of a horseshoe magnet, with a heavy armature attached to its poles, and mounted on a resonating board. A keyboard like that of a harmonium forms a part of the transmitting instrument, which may be made to consist of any convenient number of musical contact-breakers. It is on this principle that Dr. Gray has constructed his telephonic telegraph, in which four or more different messages may be transmitted simultaneously through the same wire. In this instrument there is a vibrator at the receiving station, tuned so as to be affected only by its corresponding transmitter at the other station; and, by employing intermediate receivers of different notes along a wire, the signals belonging to each are automatically transmitted, and the others are allowed to pass.

ARTICULATING OR SPEAKING TELEPHONES.—Of these instruments three classes may be recognized:

1. Those which operate through variations in the electro-motive force of the current; 2. Those which operate through changes in resistance of the medium through which the current passes; and 3. Those which are caused to operate mechanically through chemical changes produced by the current.

4105.

I. Telephones depending on Changes in Electro-motive Force.—*Bell's Telephone* was invented by Prof. Alexander Graham Bell in 1876. It consists essentially of a bar-magnet surrounded by a coil of insulated wire which is in circuit with the conducting wire. In front of the magnet a thin membrane or diaphragm is disposed. The receiving and transmitting instruments are alike. The general arrangement of magnets, diaphragms, coils, and wire in a telephone circuit will be understood from Fig. 4105. The actual construction of the instrument is shown in Fig. 4106, which is a longitudinal section. *E* is the diaphragm, of thin iron plate. *F* is the case or holder, usually of hard rubber. *B* is the silk-covered coil wound upon a wooden spool. This wire is extended along inside of the case, and connects with the line-wire through the binding-screws *D*. *A* is a steel cylindrical magnet, about 5 in. long and three-eighths of an inch in diameter. Its distance from the diaphragm is adjusted by the screw shown at its rear end.

The action of the Bell telephone is commonly explained as follows: When sound-waves are projected against the diaphragm, it is set in motion and caused to vibrate in front of the pole of the electro-magnet. By this action a series of variations in the strength of the currents are induced, proportionate to and synchronous with the variations in the movement of the diaphragm, and these variations are transmitted by the connecting wire to the receiving instrument, and are reproduced there and converted into sonorous vibrations by the diaphragm.

This theory is not generally accepted, some physicists tracing the source of sound to molecular vibrations in the magnetic coil. Experiments by M. Adet favor this last-mentioned view, and their outcome is the telephone receiver represented in Fig. 4107, where an iron wire or a strongly magnetized needle *M* is soldered at each end to a mass of copper, *E* and *D*, and surrounded by a bobbin of insulated wire *N*. The copper is soldered to a mass of lead *C*, which is perforated longitudinally at *O* to allow the ends of the coil to pass to the binding-screws at *F*, by which the telephone is connected to the circuit. The metal mass *D C* is phonetically insulated by a sheet of India-rubber *H*. An ear-piece *A* is fitted to the instrument; and on listening into it while the vibratory currents flow in the coil, the sounds are distinctly audible. M. du Moncel explains the action of this telephone in conformity with the molecular theory, by supposing that the vibratory currents of the coil lengthen and shorten the iron core, which therefore communicates a series of small shocks to the more inert metallic masses with which it is in contact.

4107

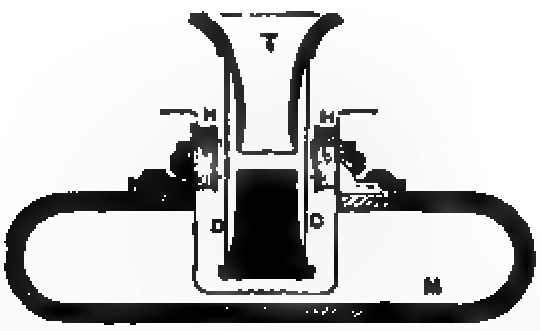
Gower's Telephone, devised by Mr. F. A. Gower, is an improved form of Bell's device, the modification in shape contributing to the greater distinctness and loudness of the sounds emitted. As shown in Fig. 4108, which represents the interior of the instrument, the magnet describes a segment of a circle, the narrow oblong poles, which are brought close together in the middle of the chord, being wound with flat coils of fine wire, each having a resistance of 60 ohms. The diaphragm is a soft iron plate 3¾ in. in diameter. The box is of brass. The "call" consists of a melodeon reed fixed to the under side of the diaphragm, opposite a narrow slit cut in the latter. A sharp puff of air sent through the speaking-tube passes through this aperture and agitates the reed, which, vibrating, transmits its note over the telephone wire.

Phelps's Telephone, Fig. 4109, devised by Mr. G. M. Phelps, consists of a permanent bar-magnet *M*,

bent so that the poles are brought near to each other. Attached to brackets on the poles are two coils H and H', opposite to which are the two diaphragms D and D'; and between them is a central mouth-piece T, opening into a chamber in which the pulsations of the air in talking act upon the diaphragm through lateral openings. The coils are connected together so that the currents generated by the vibrations of the diaphragm are in the same direction when united, and are consequently much stronger than when only one coil is employed.

4110.

4109.



A similar instrument receives the messages at the other end of the line. There is another form of Phelps's instrument, which consists of a mouth-piece placed at the upper part of an oval ebonite case containing a bent magnet connected to the bar carrying the coil behind the diaphragm, the other pole being attached to the periphery of the diaphragm in the same manner as are the bar-magnets in the crown telephone shown in Fig. 4110. This consists of an ordinary combination of bar-magnet, diaphragm, and coil; but in addition there is a group of six permanent magnets bent into circular form, and having their similar poles joined to the central bar carrying the coil. The other ends of these magnets are attached to the edge of the coil.

II. Telephones depending on Changes of Electrical Resistance.—*Edison's Carbon Telephone.*—Dr. Thomas A. Edison has made the discovery that, when properly prepared, carbon possesses the remarkable property of changing its resistance with pressure, and that the ratios of these changes correspond exactly to the pressure. On this principle is constructed the telephone shown in Fig. 4111. The carbon disk is represented at E, near the diaphragm A, which is placed between platinum plates D and G connected with the battery circuit. A small piece of rubber tubing B is attached to the centre of the metallic diaphragm, and presses lightly against an ivory piece C, which is placed directly

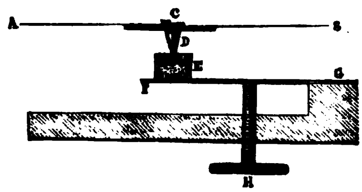
4112.

over one of the platinum plates. When therefore any motion is given to the diaphragm, it is immediately followed by a corresponding pressure upon the carbon, and by a change of resistance in the latter. Any electro-magnet, properly fitted with an iron diaphragm, serves as a receiving instrument in connection with this apparatus. An improved form of this device is represented in Fig. 4112. In this the carbon disk is contained within an ebonite ring, screwed to the metallic portion of the frame forming one of the connections of the circuit, and the carbon button rests upon this metallic surface. The other face of the button is covered with a disk of platinum foil, connected to an insulated terminal, and forming the other circuit connection; this foil is cemented to a disk of glass, in the centre of which is placed an aluminum stud that bears against the diaphragm of the instrument.

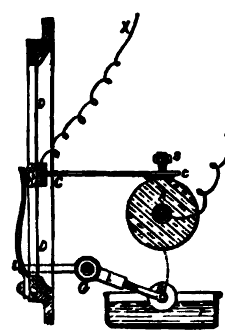
The Righi Telephone, Fig. 4113, was devised by Prof. Augusto Righi of Bologna. The receiving instrument differs but little from that of the Bell telephone. The transmitter, which is entirely different, contains a conducting powder, which is more or less pressed upon by the vibrating body; and as the conductivity of the powder varies with the pressure, the intensity of the electric current

which passes will be relatively varied with the vibrations, and the receiver, if placed in the circuit, will reproduce the sounds. In this transmitter, a membrane of parchment paper is vibrated by the sound-waves, but a metallic sheet or a membrane of wood may be used. In the centre of the membrane *A B* is fixed a piece of metal *C D*, the lower end of which has the form of a flat piston, and rests upon the powder contained in the thimble *E*. The spring *F G* carries the thimble *E*, and the elastic force of the spring is regulated by a screw *H*. When the pressure upon the powder is once adjusted,

4113.



4114.



which is easily done, the apparatus will work for a long time without readjustment. The best results have been obtained with powder composed of a mixture of carbon or plumbago and silver.

The principle of the telephones above described is the same as that of the MICROPHONE, which see.

III. THE ELECTRO-CHEMICAL TELEPHONE.—About the year 1872, Dr. T. A. Edison made the discovery that if a strip of paper, moistened with a chemical solution that is readily decomposed when a current of electricity is passed through it, be drawn over a metal plate connected with the positive pole of a voltaic battery and beneath a platinum style, bearing upon it with a gentle pressure, and which can be connected to the negative pole by means of a key or contact-maker, whenever the current is allowed to pass the friction is instantly reduced between the surface of the prepared paper and the platinum style, to be immediately restored the moment the current is again interrupted; from which it follows that if the paper be drawn with a uniform tractive force below the style, it will slip whenever an electrical current is transmitted through it, and will be retarded again by a frictional resistance the moment that the current ceases to flow. This discovery has been applied by Dr. Edison to the construction of a telephone which is remarkable for the loudness and clearness of its tones. Fig. 4114 is a diagram showing the arrangement of the device. The cylinder *A* is composed of precipitated chalk to which a small proportion of acetate of mercury is added, the whole being moistened with a saturated solution of caustic potash, and moulded into a cylindrical form by being subjected to hydraulic pressure. This cylinder is mounted upon a horizontal axis *B*, and is made by suitable mechanism to revolve beneath a metallic strip *C*, which is maintained with a uniform pressure by an adjustable spring *S* against the surface of the chalk. At the point where the strip rests upon the cylinder, a small plate of platinum is fastened, and the opposite end of the strip is attached to the centre of a diaphragm of mica *D*, 4 in. in diameter, firmly fixed to the framing of the instrument by its circumference. By connecting the strip to the zinc element of a voltaic battery, and the chalk cylinder to the copper pole, and rotating the cylinder at a uniform speed away from the diaphragm, it will be found that, when no current is passing, the friction between the moistened surface of the chalk and the platinum strip is sufficient to drag the centre of the diaphragm inward, and it will take up a fixed position of equilibrium when the frictional pull in the centre of the diaphragm is equal to the elastic tension of the strained diaphragm. The moment, however, that an electric current is allowed to pass between the strip and the cylinder, electro-chemical decomposition takes place, the friction between them is reduced, and the diaphragm, finding its elastic tension unopposed, flies back to a second position of equilibrium dependent upon similar conditions; and if a variable or undulatory current of electricity be transmitted through the instrument, the diaphragm will be kept in continual motion by the constantly varying friction existing between the chalk and the platinum, dragging the diaphragm in opposition to its own constant elastic tension. *G* is a counter-shaft which can be turned through a small angle by depressing a lever keyed on to it on the outside of the case; the effect of this is to raise by means of the forked lever *L L* the damping roller *R* against the surface of the chalk cylinder, and so occasionally to supply the water which is lost by evaporation. The roller when not in use rests in a trough of water *T*.

In another form of this apparatus the movable roller is dispensed with, and the cylinder is inclosed in a vulcanite box seen at the end of the movable arm in Fig. 4115, which represents the telephone with all its accessories. The small shaft that runs parallel with the iron arm extends through the side of the box and carries the chalk cylinder. Upon the opposite end there is a small pinion moved by a worm, the crank of which is turned by the finger. The diaphragm of the receiving instrument is covered by the front of the box, excepting a small central portion which is quite sufficient for the exit of the sound. The arm which supports the receiving instrument is jointed so that it may be raised vertically out of the way when the telephone is not in use. The transmitter is contained in the stationary rectangular box; its mouth-piece projects slightly, and the diaphragm, which is of mica, is supported by a metal frame and springs inside the box cover. The details of its construction will be understood from Fig. 4116. A vulcanite arm is secured to the centre of the mica diaphragm by means of a small bolt, which is connected with one pole of the battery by a piece of metallic foil or very thin copper wire. The head of this bolt is platinum-faced, and sunk deeply in the vulcanite arm, the same cavity containing also a piece of carbon pencil, such as is used for electric candles. The carbon fits the cavity loosely and is rounded at both ends. Its outer end is

pressed by a platinum-faced spring secured to the outer end of the vulcanite arm. The spring carries at its free end, exactly opposite the piece of carbon, a brass weight, and the pressure of the spring upon the carbon is regulated by the small set-screw. A wire or piece of copper foil, connecting with the spring, completes an electrical circuit, which includes the primary of an induction coil contained by the rectangular box. The secondary wire of the induction coil is connected with the telephonic line, and a tertiary coil which envelops the secondary is connected with the rubber and chalk cylinder of the receiving instrument. Below the transmitter-box are two keys, the right-hand one being used for signaling, the left-hand one for completing the tertiary circuit when a message is received.

The operation of the instrument is as follows: The vibration of the diaphragm of the transmitting instrument varies the contact between the carbon and the two electrodes, so that a varying current is sent through the primary of the induction coil; this of course produces a secondary current of varying intensity in the secondary wire of the induction coil, which, being in circuit with the secondary wire of the induction coil of a distant instrument, produces a current in the tertiary wire wound around the secondary coil. The tertiary current passes through the chalk cylinder and the platinum-faced rubber, and as the chalk cylinder revolves the friction of the rubber is varied according to the variation of the primary, secondary, and tertiary currents. The platinum-faced rubber is connected with the diaphragm, and the friction of the rubber is sufficient, when no current passes, to pull the diaphragm forward as the cylinder is turned; but when the slightest current is sent through the primary coil, the induced tertiary current transforms the frictional surface of the chalk into a frictionless surface, and the diaphragm springs back. All this is necessary to describe a single vibration of the diaphragm, thousands of which vibrations are required for the utterance of a single sentence.

Works for Reference.—"The Speaking Telephone, Talking Phonograph, and other Electrical Novelties," Prescott, New York, 1878; "The Telephone," Dolbear, New York, 1878. See also files of the *Scientific American*, *Engineering*, *Engineer*, *Mechanic's Magazine*, *Journal of the Society of Arts*, *Scientific News*, *Journal of the Telegraph*, and other technical periodicals, since 1876.

TEMPERING AND HARDENING METALS. When the malleable metals are hammered or rolled, they generally increase in hardness, in elasticity, and in density or specific gravity, which effects are produced simply from the closer approximation of their particles; and in this respect steel may be perhaps considered to excel, as the process called hammer-hardening, which simply means hammering without heat, is frequently employed as the sole means of hardening some kinds of steel springs, and for which it answers remarkably well. After a certain degree of compression, the malleable metals assume their closest and most condensed states; and it then becomes necessary to discontinue the compression or elongation, as it would cause the disunion or cracking of the sheet or wire, or else the metal must be softened by the process of annealing.

The metals lead, tin, and zinc are by some considered to be perceptibly softened by immersion in boiling water; but such of the metals as will bear it are generally heated to redness, the cohesion of the mass is for the time reduced, and the metal becomes as soft as at first; and the working and annealing may be thus alternately pursued, until the sheet metal or the wire reaches its limit of tenuity. The generality of the metals and alloys suffer no very observable change, whether or not they are suddenly quenched in water from the red heat. Pure hammered iron, like the rest, appears after annealing to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion, but only to an extent that is rather hurtful than useful, and which may be considered as an accidental quality. Steel, however, receives by sudden cooling that extreme degree of hardness combined with tenacity which places it so incalculably beyond every other material for the manufacture of cutting tools; especially as it likewise admits of a regular gradation from extreme hardness to its softest state, when subsequently reheated or *tempered*. In the process of hardening steel, water is by no means essential, as the sole object is to extract its heat rapidly; and the following are examples, commencing with the condition of extreme hardness, and ending with the reverse condition.

A thin heated blade placed between the cold hammer and anvil, or other good conductors of heat, becomes perfectly hard. Thicker pieces of steel, cooled by exposure to the air upon the anvil, be-

come rather hard, but readily admit of being filed. They become softer when placed on the cold cinders or other bad conductors of heat; still more soft when placed in hot cinders, or within the fire itself, and cooled by their gradual extinction. When the steel is encased in close boxes with charcoal powder, and is raised to a red heat and allowed to cool in the fire or furnace, it assumes its softest state; unless, lastly, we proceed to its partial decomposition. This is done by inclosing the steel with iron turnings or filings, the scale from the smith's anvil, lime, or other matters that will abstract the carbon from its surface; by this mode it is superficially decarbonized, or reduced to the condition of pure soft iron.

A nearly similar variety of conditions might be referred to as existing in cast iron in its ordinary state, governed by the magnitude, quality, and management of the castings; independently of which, by one particular method, some cast iron may be rendered externally as hard as the hardest steel: such are called *chilled-iron castings;* and, as the opposite extreme, by a method of annealing combined with partial decomposition, *malleable-iron castings* may be obtained, so that cast-iron nails may be clinched. (See Casting.) Again, the purest iron, and most varieties of cast iron, may by another proceeding be superficially converted into steel, and then hardened, the operation being appropriately named *case-hardening.*

The temperature suitable to forging and hardening steel differs in some degree with its quality and its mode of manufacture: the heat that is required diminishes with the increase of carbon. In every case the lowest available temperature should be employed in each process, the hammering should be applied in the most equal manner throughout, and for cutting tools it should be continued until they are nearly cold. Coke or charcoal is much better as a fuel than fresh coal, the sulphur of which is highly injurious. The scale should be removed from the face of the work, to expose it the more uniformly to the effect of the cooling medium. Hardening a second time without the intervention of hammering is attended with increased risk; and the less frequently steel passes through the fire the better.

Heating.—The smallest works are heated with the flame of the blow-pipe, and are occasionally supported upon charcoal. (See Soldering.) For objects that are too large to be heated by the blow-pipe, and too small to be conveniently warmed in the naked fire, various protective means are employed. Thus an iron tube or sheet-iron box inserted in the midst of the ignited fuel is a safe and cleanly way; it resembles the muffle employed in chemical works. The work is then managed with long forceps made of steel or iron wire, bent in the form of the letter U, and flattened or hollowed at the ends. A crucible or an iron pot about 4 to 6 in. deep, filled with lead and heated to redness, is likewise excellent, but more particularly for long and thin tools, such as gravers for artists, and other slight instruments; several of these may be inserted at once, although toward the last they should be moved about to equalize the heat. The weight of the lead makes it desirable to use a bridle or trevet for the support of the crucible. Some workmen place on the fire a pan of charcoal dust, and heat it to redness.

Great numbers of tools, both of medium and large size, are heated in the ordinary forge-fire, which should consist of cinders rather than fresh coals. To prevent decarbonization for ordinary work, charcoal instead of coal is sometimes used; and where hardening is not done continuously, this is a good practice, because a few pieces of charcoal can be thrown on the fire, and the latter thus rendered ready for use in a few minutes. Green coal should never be used for heating the steel for the hardening, even if it is for the forging process. A coke suitable for heating to harden should always be kept on hand. To make it, build a large fire of small soft coal, well wetted and banked, and with a round bar make holes for the blast to come through. When the gas is burnt out of the interior and the outside is well caked, the heap may be broken up, so that the gas may be burned from the outside. This done, the blast is stopped and the coke stowed away for use.

In heating the work, the greatest care should be taken to communicate to all the parts requiring to be hardened a uniform temperature, and this is only to be arrived at by cautiously moving the work to and fro to expose all parts alike to the fire; the difficulty of accomplishing it of course increases with long objects, for which fires of proportionate length are required. It is far better to err on the side of deficiency than of excess of heat; the point is rather critical, and not alike in all varieties of steel. Until the quality of the steel is familiarly known, it is a safe precaution to commence rather too low than otherwise, as then the extent of the mischief will be the necessity for a repetition of the process at a higher degree of heat; but the steel if burned or overheated will be covered with scales, and what is far worse, its quality will be permanently injured. A good hammering will in a degree restore it; but this in finished works is generally impracticable.

If a piece of hardened tool-steel shows a brightness and crystalline formation under fracture, it probably has been burned; if the fracture is dull and even, the reverse is true. When a piece of work will be improved by having its exterior hardened and tempered with the interior left softer, it may be heated in melted lead, the latter being covered with charcoal to prevent oxidation. It is an excellent plan to heat the steel in some flux. The Waltham Watch Company heat their hair-springs in melted glass. The Pratt & Whitney Company heat their taps in a mixture of equal quantities of cyanide of potash and salt. The Morse Twist-Drill Company use a similar mixture. The object of heating in these materials is to prevent the loss of carbon in the steel, which is of great consequence in small or slight articles.

Cooling.—The choice of cooling mediums has reference mainly to the relative powers of conducting heat they severally possess. The following have been at different times resorted to with various degrees of success: currents of cold air, and immersion in water in various states, in oil or wax, and in freezing mixtures. Mercury and flat metallic surfaces have been also used. Jacob Perkins recommended, as the result of his experiments, plain water at a temperature of 40° F. Mercury is considered by some to give the greatest degree of hardness; then cold salt and water, or water mixed with various "astringent and acidifying matters;" plain water follows; and lastly, oily mixtures.

With plain water, an opinion very largely exists in favor of that which has been used over and over again even for years, provided it is not greasy; and when the steel is very harsh, the chill is taken off plain water to lessen the risk of cracking it. Oily mixtures impart to thin articles, such as springs, a sufficient and milder degree of hardness, with less danger of cracking than from water; and in some cases a medium course is pursued by covering the water with a thick film of oil, which is said to be adopted occasionally with scythes, reaping-hooks, and thin edge-tools. As a rule, plain cold water is best for general purposes; but for thin elastic works, oil, or oily compositions, are certainly more proper.

A so-called natural spring is made by a vessel with a true and a false bottom, the latter perforated with small holes; it is filled with water, and a copious supply is admitted beneath the partition; it ascends through the holes, and pursues the same current as the heated portions, which also escape at the top. This was invented by Jacob Perkins, and was used by him in hardening the rollers for transferring the impressions to the steel plates for bank-notes. Sometimes, when neighboring parts of works are required to be respectively hard and soft, metal tubes or collars are fitted tight upon the work, to protect the parts to be kept soft from the direct action of the water, at any rate for so long a long a period as they retain the temperature suitable to hardening.

The process of hardening is generally one of anxiety, as the sudden transition from heat to cold often causes the works to become greatly distorted if not cracked. The latter accident is much the most likely to occur with thick massive pieces, which are, as it were, hardened in layers; as, although the external crust or shell may be perfectly hard, there is almost a certainty that toward the centre the parts are gradually less hard, and when broken the inner portions will sometimes admit of being readily filed. When in the fire the steel becomes altogether expanded, and in the water its outer crust is suddenly arrested, but with a tendency to contract from the loss of heat, which cannot so rapidly occur at the central part; it may be therefore presumed that the inner bulk continues to contract after the outer crust is fixed, which tends to tear the two asunder, the more especially if there be any defective part in the steel itself. An external flake of greater or less extent not unfrequently shells off in hardening; and it often happens that works remain unbroken for hours after removal from the water, but eventually give way and crack with a loud report, from the rigid unequal tension produced by the violence of the process of hardening.

The contiguity of thick and thin parts is also highly dangerous, as they can neither receive nor yield up heat in the same times; the mischief is sometimes lessened by binding pieces of metal around the thin parts with wire, to save them from the action of the cooling medium. Sharp angular notches are also fertile sources of mischief, and, where practicable, they should be rejected in favor of curved lines.

As regards both cracks and distortions, it may perhaps be generally said that their avoidance depends principally upon manipulation, or the successful management of every step: first, the original manufacture of the steel, its being forged and wrought so that it may be equally condensed on all sides with the hammer; otherwise, when the cohesion of the mass is lessened from its becoming red-hot, it recovers in part from any unequal state of density in which it may have been placed. While red-hot, it is also in its weakest condition, and is prone to injury either from incautious handling with the tongs, or from meeting the sudden cooling action irregularly; and therefore it is generally best to plunge works vertically, as all parts are then exposed to equal circumstances, and less disturbance is risked than when the objects are immersed obliquely or sideways into the water; although for swords, and objects of similar form, it is found the best to dip them exactly as in making a vertical downward cut with a sabre, which for this weapon is its strongest direction.

Very slight tools may be prevented from cracking by heating the water to about 100°, immersing them slowly and perpendicularly deep into the water, and then holding them quite still until cold. Much of the cracking of steel during the hardening process arises from removing the articles from the water before they are reduced to the same temperature as the water. The cutters for milling machines are very apt to flaw during the hardening; but this may be avoided as follows: Sling the cutter by a wire passing through the hole, and fastened to a small plate upon which the cutter may rest; then fill the hole with fire-clay. Dip the cutter vertically, and hold it still near the bottom of the water until it is cooled.

Occasionally objects are clamped between stubborn pieces of metal, as soft iron or copper, during their passage through the fire and water. Such plans can be seldom adopted and are rarely followed, the success of the process being mostly allowed to depend exclusively upon good general management. In experiments in making the magnets for dipping-needles, which are about 10 inches long, one-fourth of an inch wide, and the two-hundredth part of an inch thick, this precaution entirely failed, and the needles assumed all sorts of distortions when released from between the stiff bars within which they were hardened. The plan was eventually abandoned, and the magnets were heated in the ordinary way within an iron tube, and were set straight with the hammer after being let down to a deep orange or brown color. Steel, however, is in the best condition for the formation of good permanent magnets when perfectly hard.

In all cases the thick unequal scale left from the forge should be ground off before hardening, in order to expose a clean metallic surface; otherwise the cooling medium cannot produce its due and equal effect throughout the instrument. The edges also should be left thick, that they may not be burned in the fire; thus it will frequently happen that the extreme end or edge of a tool is inferior in quality to the part within, and that the instrument is much better after it has been a few times ground.

When a wedge-shaped or thin tool, such as a drill, requires to be tempered at and near the cutting edge only, and it is desirable to leave the other part or parts soft, the tempering is performed by heating the steel for some little distance back from the cutting edge, and then immersing the cutting edge and about one-half of the rest of the steel, which is heated to as high a degree as a red heat, in the

water until it is cold; then withdraw the tool and brighten the surface which has been immersed by rubbing it with a piece of soft stone (such as a piece of a worn-out grindstone) or a piece of coarse emery-cloth, the object of brightening the surface being to cause the colors (described farther on) to show themselves distinctly. The instant this operation has been performed, the brightened surface should be lightly brushed by switching the finger rapidly over it; for unless this is done, the colors appearing will be false colors, as will be found by neglecting this latter operation, in which case the steel after quenching will be of one color, and if then wiped will appear of a different hue. A piece of waste or other material may of course be used in place of the hand. The heat of that part of the tool which has not been immersed will become imparted to that part which was hardened, and, by the deepening of the colors, denote the point of time at which it is necessary to again immerse the tool and quench it altogether cold.

The operation of the first dipping requires some little judgment and care; for if the tool is dipped a certain distance and held in that position without being moved till the end dipped is cold, and the tempering process is proceeded with, the colors from yellow to green will appear in a narrow band, and it will be impossible to directly perceive when the cutting edge is at the exact shade of color required; then, again, the breadth of metal of any one degree of color will be so small that orce grinding the tool will remove it and give us a cutting edge having a different degree of temper or of hardness. The first dipping should be performed thus: Lower the tool vertically into the water to about one-third of the distance to which it is red-hot, hold it still for about sufficient time to cool the end immersed, then suddenly plunge it another third of the distance to which it is heated red, and withdraw it before it has had time to become more than half cooled. By this means the body of metal between the cutting edge and the part behind, which is still red-hot, will be sufficiently long to cause the variation in the temperature of the tool end to be extended in a broad band, so that the band of yellow will extend some little distance before it deepens into a red; hence it will be easy to ascertain when the precise degree of color and of temper is obtained, when the tool may be entirely quenched. A further advantage of this plan of dipping is, that the required degree of hardness will vary but very little in consequence of grinding the tool; and if the operation is carefully performed, the tool can be so tempered that, by the time it has lost the required degree of temper from being ground back, it will also require reforging or reforming. As a rule a tool should be made to a red heat to a distance about twice the diameter of the tool-steel of which it is made. A number of special instances of hardening are grouped below.

TEMPERING.—Between the extreme conditions of hard and soft steel there are many intermediate grades, the common index for which is the oxidation of the brightened surface, and it is quite sufficient for practice. These tints, and their respective approximate temperatures, are thus tabulated:

1. Very pale straw-yellow	430°	7. Light purple	530°
2. A shade of darker yellow	440	8. Dark purple	550
3. Darker straw-yellow	470	9. Dark blue	570
4. Still darker straw-yellow	490	10. Paler blue	590
5. A brown yellow	500	11. Still paler blue	610
6. A yellow tinged slightly with purple	520	12. Still paler blue, with a tinge of green	630

The first tint arrives at about 430° F., but it is only seen by comparison with a piece of steel not heated. The tempering colors differ slightly with the various qualities of steel.

The Tempering Scale, represented in the colored plate given herewith, was devised by the editor of this work and Mr. Joshua Rose, as a guide to the temperer in selecting the colors appropriate to different tools. In all tools, and especially in costly ones, it is desirable to give the exact degree of temper which experiment has determined as the best. It will be noted that in the color-test the shades of yellow alone extend over a range of 70° of temperature. Tool-users know that within these 70° lies a wide range of hardness; and when it is remembered how widely opinions will differ as to what is any specified shade or tint of color, it will be evident that in the yellows alone there is considerable room for error if the temperer is simply told the color to which a tool is to be hardened.

The scale here presented is an exact facsimile of a bar of polished steel hardened and then tempered to all the colors exhibited. In order to discover the best practice on tempering, and also to verify the colors, copies of the scale were forwarded to a large number of manufacturers, with the request that they would indicate by marks on the scale the colors to which they tempered the various tools which they made a specialty of producing. From the data thus collected, and also from the results of a series of practical experiments, the scale has been marked to adapt it to the principal tools. The user finds the name of the tool which he desires to temper on the scale, and notes the color opposite the mark. To this color, or to as near an approximation as possible, the steel should be tempered. Where special steels are employed, some slight changing of the relative position of the marks may be needful, as they are here adapted to good quality American tool-steel. A little experimenting, however, will soon exhibit the amount of variation for any particular kind of metal, and this amount is easily applied as a correction to the indications here given.

The heat for tempering being moderate, it is often supplied by the part of the tool not requiring to be hardened, and which is not therefore cooled in the water. The workman first hastily tries with a file whether the work is hard; he then partially brightens it at a few parts with a piece of grindstone or an emery stick, that he may be enabled to watch for the required color; which attained, the work is usually cooled in any convenient manner, lest the body of the tool should continue to supply heat. But when, on the contrary, the color does not otherwise appear, partial recurrence is had to the mode in which the work was heated, as the flame of the candle or the surface of the clear fire, applied if possible a little below the part where the color is to be observed, that it may not be soiled by the smoke.

A very convenient and general manner of tempering small objects is to heat to redness a few

inches of the end of a flat bar of iron about two feet long; it is laid across the anvil, or fixed by its cold extremity in the vise, and the work is placed on that part of its surface which is found by trial to be of the suitable temperature, by gradually sliding the work toward the heated extremity. In this manner many tools may be tempered at once, those at the hot part being pushed off into a vessel of water or oil, as they severally show the required color; but it requires dexterity and quickness in thus managing many pieces. Vessels containing oil or fusible alloys carefully heated to the required temperatures have also been used. The method called "blazing off" is resorted to for many articles, such as springs and saws, by heating them over the naked fire until the oil, wax, or composition in which they have been hardened ignites; this can only occur when they respectively reach their boiling temperatures and are evaporated in the gaseous form.

The period of letting down the work is also commonly chosen for correcting, by means of the hammer, those distortions which so commonly occur in hardening; this is done upon the anvil, either with the thin pene of an ordinary hammer, or else with a hack-hammer, a tool terminating at each end in an obtuse chisel-edge, which requires continual repair on the grindstone. The blows are given on the hollow side of the work, and at right angles to the length of the curve; they elongate the concave side, and gradually restore it to a plane surface, when the blows are distributed consistently with the positions of the erroneous parts. The hack-hammer unavoidably injures the surface of the work, but the blows should not be violent, as they are then also more prone to break the work, the liability to which is materially lessened when it is kept at or near the tempering heat, and the edge of the hack-hammer is slightly rounded.

Watchmakers' drills of the smallest kinds are heated in the blue part of the flame of the candle. Larger drills are heated with the blow-pipe flame, applied very obliquely, and a little below the point. When very thin they may be whisked in the air to cool them, but they are more generally thrust into the tallow of the candle or the oil of the lamp. They are tempered either by their own heat, or by immersion in the flame below the point of the tool.

For tools between those suited to the action of the blow-pipe and those proper for the open fire, there are many which require either the iron tube or the bath of lead or charcoal; but the greater number of works are hardened in the ordinary smith's fire, without such defenses. Tools of moderate size, such as the majority of turning tools, carpenters' chisels and gouges, and so forth, are generally heated in the open fire: they require to be continually drawn backward and forward through the fire, to equalize the temperature applied. They are plunged vertically into the water, and then moved about sideways to expose them to the cooler portions of the fluid. If needful, they are only dipped to a certain depth, the remainder being left soft. Some persons use a shallow vessel filled only to the height of the portion to be hardened, and plunge the tools to the bottom; but this strict line of demarkation is sometimes dangerous, as the tools are apt to become cracked at the part, and therefore a small vertical movement is also generally given, that the transition from the hard to the soft part may occupy more length.

Razors and penknives are too frequently hardened without the removal of the scale arising from the forging; this practice, which is not used with the best works, cannot be too much deprecated. The blades are heated in a coke or charcoal fire, and dipped into the water obliquely. In tempering razors, they are laid on their backs upon a clear fire, about half a dozen together, and they are removed one at a time, when the edges, which are as yet thick, come down to a pale straw-color; should the backs accidentally get heated beyond the straw-color, the blades are cooled in water, but not otherwise. Penknife blades are tempered, a dozen or two at a time, on a plate of iron or copper, about 12 in. long, 3 or 4 in. wide, and about a quarter of an inch thick; the blades are arranged close together on their backs, and lean at an angle against each other. As they come down to the temper, they are picked out with small pliers and thrown into water, if necessary; other blades are then thrust forward from the cooler parts of the plate to take their place.

Hatchets, adzes, cold chisels, and numbers of similar tools, in which the total bulk is considerable compared with the part to be hardened, are only partially dipped; they are afterward let down by the heat of the remainder of the tool, and when the color indicative of the temper is attained they are entirely quenched. With the view of removing the loose scales, or the oxidation acquired in the fire, some workmen rub the objects hastily in dry salt before plunging them in the water, in order to give them a cleaner and whiter face.

In hardening large dies, anvils, and other pieces of considerable size, by direct immersion, the rapid formation of steam at the sides of the metal prevents the free access of the water for the removal of the heat with the required expedition; in these cases, a copious stream of water from a reservoir above is allowed to fall on the surface to be hardened. This contrivance is frequently called a "float;" and although the derivation of the name is not very clear, the practice is excellent, as it supplies an abundance of cold water, which, as it falls directly on the centre of the anvil, is sure to render that part hard. It is, however, rather dangerous to stand near such work at the time, as, when the anvil face is not perfectly welded, it sometimes in part flies off with great violence and a loud report. Occasionally the object is partly immersed in a tank beneath the fall of water, by means of a crane and slings; it is ultimately tempered with its own heat, and dropped in the water to become entirely cold.

Oil, or various mixtures of oil, tallow, wax, and resin, are used for many thin and elastic objects, such as needles, fish-hooks, steel pens, and springs, which require a milder degree of hardness than is given by water. For example, steel pens are heated in large quantities in iron trays within a furnace, and are then hardened in an oily mixture; generally they are likewise tempered in oil, or a composition the boiling-point of which is the same as the temperature suited to letting them down. This mode is particularly expeditious, as the temper cannot fall below the assigned degree. The dry heat of an oven is also used, and both the oil and oven may serve for tempers harder than that given by boiling oil; but more care and observation are required for these lower temperatures.

Saws and springs are generally hardened in various compositions of oil, suet, wax, and other ingredients. The composition used by an experienced saw-maker is two pounds of suet and a quarter of a pound of beeswax to every gallon of whale-oil; these are boiled together, and will serve for thin works and most kinds of steel. The addition of black resin, to the extent of about one pound to the gallon, makes it serve for thicker pieces and for those it refused to harden before; but the resin should be added with judgment, or the works will become too hard and brittle. The composition is useless after it has been constantly employed for about a month: the period depends, however, on the extent to which it is used, and the trough should be thoroughly cleaned out before new mixture is placed in it. The following recipe is recommended by an experienced workman: "20 gallons of spermaceti oil; 20 lbs. of beef suet rendered; 1 gallon of neatsfoot oil; 1 lb. of pitch; 3 lbs. of black resin. These two last articles must be previously melted together, and then added to the other ingredients; when the whole must be heated in a proper iron vessel, with a close cover fitted to it, until the moisture is entirely evaporated, and the composition will take fire on a flaming body being presented to its surface, but which must be instantly extinguished again by putting on the cover of the vessel." The above ingredients lose their hardening property after a few weeks' constant use. The saws are heated in long furnaces, and then immersed horizontally and edgewise in a long trough containing the composition; two troughs are commonly used, the one until it gets too warm, then the other for a period, and so on alternately. Part of the composition is wiped off the saws with a piece of leather when they are removed from the trough, and they are heated one by one over a clear coke fire, until the grease inflames; this is called "blazing off." When the saws are wanted to be rather hard, but little of the grease is burned off; when milder, a larger portion; and for a spring temper, the whole is allowed to burn away. When the work is thick, or irregularly thick and thin, as in some springs, a second and third dose is burned off, to insure equality of temper at all parts alike. Gun-lock springs are sometimes literally *fried in oil* for a considerable time over a fire in an iron tray; the thick parts are then sure to be sufficiently reduced, and the thin parts do not become more softened from the continuance of the blazing heat. Springs and saws appear to lose their elasticity, after hardening and tempering, from the reduction and friction they undergo in grinding and polishing. Toward the conclusion of the manufacture, the elasticity of the saw is restored principally by hammering, and partly by heating it over a clear coke fire to a straw-color: the tint is removed by very dilute muriatic acid, after which the saws are well washed in plain water and dried.

Watch-springs are hammered out of round steel wire, of suitable diameter, until they fill the gauge for width, which at the same time insures equality of thickness; the holes are punched in their extremities, and they are trimmed on the edge with a smooth file; the springs are then tied up with binding-wire, in a loose open coil, and heated over a charcoal fire upon a perforated revolving plate. They are hardened in oil, and blazed off. The spring is now distended in a long metal frame, similar to that used for a saw-blade, and ground and polished with emery and oil, between lead blocks. By this time its elasticity appears quite lost, and it may be bent in any direction; its elasticity is, however, entirely restored by a subsequent hammering on a very bright anvil, which "puts the nature into the spring." The coloring is done over a flat plate of iron, or hood, under which a little spirit-lamp is kept burning; the spring is continually drawn backward and forward, about two or three inches at a time, until it assumes the orange or deep-blue tint throughout, according to the taste of the purchaser; by many the coloring is considered to be a matter of ornament, and not essential. The last process is to coil the spring into the spiral form, that it may enter the barrel in which it is to be contained; this is done by a tool with a small axis and winch-handle, and does not require heat. The balance-springs of marine chronometers, which are in the form of a screw, are wound into the square thread of a screw of the appropriate diameter and coarseness; the two ends of the spring are retained by side screws, and the whole is carefully enveloped in platinum foil, and tightly bound with wire. The mass is next heated in a piece of gun-barrel closed at one end, and plunged into oil, which hardens the spring almost without discoloring it, owing to the exclusion of the air by the close platinum covering, which is now removed, and the spring is let down to the blue before removal from the screwed block.

The balance- or hair-springs of common watches are frequently left soft; those of the best watches are hardened in the coil upon a plain cylinder, and are then curled into the spiral form between the edge of a blunt knife and the thumb, the same as in curling up a narrow ribbon of paper or the filaments of an ostrich feather.

Mr. Dent says that 3,200 balance-springs weigh only one ounce; but springs also include the heaviest examples of hardened-steel works uncombined with iron: for example, of Mr. Adams's patent bow-springs for all kinds of vehicles, some intended for railway use measure 3½ ft. long, and weigh 50 lbs. each piece; two of these are used in combination: other single springs are 6 ft. long, and weigh 70 lbs. In hardening them, they are heated by being drawn backward and forward through an ordinary forge-fire, built hollow, and they are immersed in a trough of plain water. In tempering them, they are heated until the black-red is just visible at night; by daylight the heat is denoted by its making a piece of wood sparkle when rubbed on the spring, which is then allowed to cool in the air. The metal is nine-sixteenths of an inch thick, and Mr. Adams considers five eighths the limit to which steel will harden properly—that is, sufficiently alike to serve as a spring: he tests their elasticity far beyond their intended range. J. R. (in part).

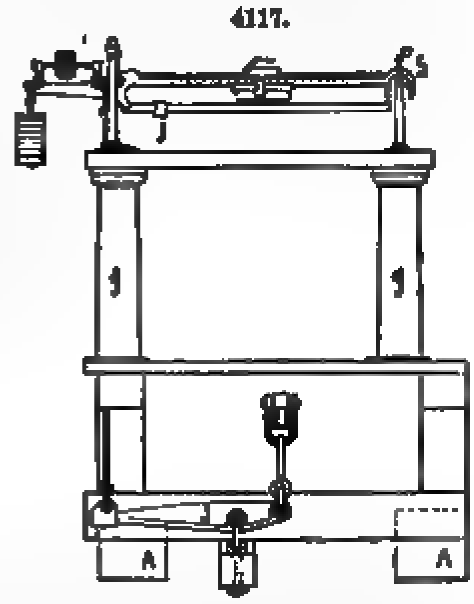
TENDER. See Locomotive, Description of Parts of the.

TENONING MACHINE. See Mortising and Tenoning Machines.

TESTING MACHINES. Instruments used for determining the strength of materials. For testing large sections of metals, requiring many tons to break them, the apparatus may be a machine of great size and strength. There are two classes of such machines: the first, which comprises the greater number, including those which weigh the amount of applied stress by means of combinations

of levers and scale-beams; and the second, those which apply the strain by means of a hydraulic press. One of the best-known testing machines of the first class was built some years ago by the late Major Wade for the United States Government. It is described in his "Reports of Experiments on Metals for Cannon," Philadelphia, 1856. Copies of this machine as improved by Gen. Rodman are in use (1879) at the Washington Navy Yard and in the United States Army building in New York.

4117.



The Fairbanks Testing Machine is represented in Figs. 4117 to 4121. The parts are as follows: A, main sills, of wood or iron; B, cross-sills supporting iron frames E; C, cross-timber which with the casting D receives the strain from the screws L; F, centre-bearings of frames E; G, four main levers suspended in frames E; H, centre-lever conveying strains from G to I; I, double lever receiving strains from H and G; J, reducing lever, conveying strains from I to h; K, wrought-iron platform-girders; L, screws for applying the strain; M, shaft with right and left worms N, which turn the gears P; R, cross-head and lower clamp; S, cast-iron uprights; T, upper clamp; U, supports for crushing or compression; V, steel wedges for holding specimen X; W, frame to steady tops of screws L; Y, cross-piece of same; a, hand-wheel for light strains and quick motion; b, gear-wheel; d, hand-wheel for heavy strains, communicating with wheel b by pinion f; g, iron columns supporting beam h, the latter being a double beam such as is used on railway-track scales; j, a small poise on the lower beam moving automatically; i, the poise on beam h.

By turning the hand-wheel a, a steady motion is given to the screws, and strain is applied to the specimen through the descent of the cross-head R. By means of the wheel d a stress of 50,000 lbs. may be applied. The uprights S are placed on the scale-platform, and support the upper clamp, which holds the specimen X. It will be seen that the only connection between the screws L and the platform is through the specimen, and therefore whatever strain is applied by the screws comes directly over the platform. It is evident that this strain may

4118. 4119.

4121.

be weighed accurately in the ordinary manner. When it is desired to crush a test-piece or to make tests of transverse strength, the two blocks U, which are movable, support the specimen and rest on the scale-platform. The cross-head R is then brought down on top of the test-piece, and the pressure is weighed the same as for tensile strains.

A test of the Fairbanks testing machine, in order to determine the accuracy of its indications, was made by Park Benjamin's Scientific Expert Office, of New York, in March, 1879. The machine was situated in the Permanent Exhibition building in Philadelphia. The experiments were conducted in the following manner:

Three coils, respectively of iron wire 0.15 in. in diameter, brass wire 0.18 in. in diameter, and braided cotton cord 0.12 in. in diameter, were provided. From each of these 20 test-pieces 8 in. in length were cut off. These pieces were broken alternately by dead weight and in the testing machine, as fast as they were cut from the coils. Those ruptured by dead weight were held in heads similar to those in the testing machine, and a cradle was hung to the lower head in which 50-lb. weights were placed until the breaking limit was nearly reached; 5-lb. weights were then added until rupture took place. In breaking the pieces in the testing machine, the quick gear was used until the breaking limit was approximated, and afterward the slow gear. In turning the wheels of the machine no pains were taken to insure regularity of movement, the speed being governed only by the movement of the automatic registering weight. Three series of experiments were conducted, in each series 10 samples of wire or cord being broken by dead weight, and 10 corresponding samples in the machine. The results were as follows:

First series: Samples of brass wire 0.18 in. in diameter. Average breaking weight in pounds of 10 samples—by dead weight, 1,106; in the testing machine, 1,106.

Second series: Samples of braided cotton cord 0.12 in. in diameter. Average breaking weight of 10 samples in pounds—by dead weight, 113.5; in testing machine, 110.5.

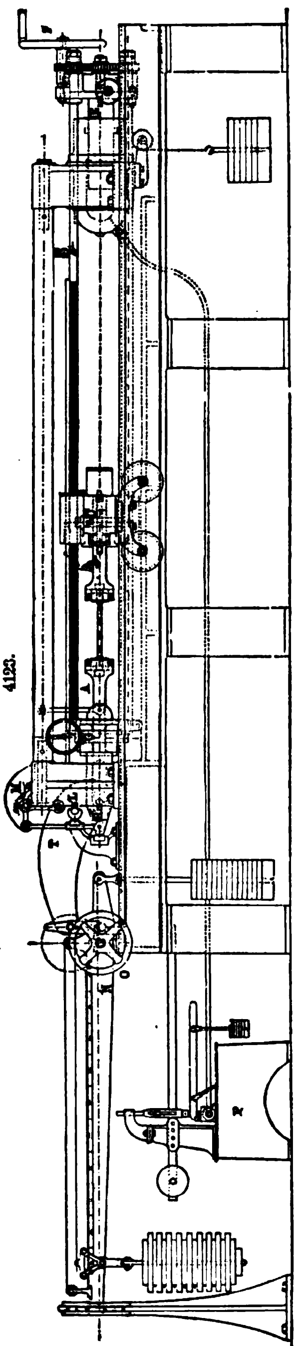
Third series: Samples of iron wire 0.15 in. in diameter. Average breaking weight of 10 samples in pounds—by dead weight, 1,521; in testing machine, 1,519.5.

It is considered that these experiments demonstrate conclusively the accuracy of the machine. The differences between the averages are less than 5 lbs., and the registry both in breaking by dead weight and in the apparatus showed differences only to the extent of 5 lbs.; so that the results are accurate to within the unit of measurement. Hence, the strain applied through the gear-wheels produces precisely the same effect as the placing of dead weights on the platform.

4122.

The Colt's Armory Testing Machine is represented in Fig. 4122. The basis of the machine is a platform scale, by which the forces applied to the specimens are weighed with the same accuracy that any load may be weighed by similar scales. *A* is the platform of a 50-ton scale, of which *B* is the weigh-beam, with its sliding weight *C*. Upon the platform a cast-iron frame *D* is placed, to sustain the nut of a screw *E*, to the lower end of which are applied the fixtures for holding the upper end of a specimen intended to receive a tensile strain. The platform is 5 ft. long by 3 ft. wide, and has an oblong opening in its centre, through which two long screws rise about 2 ft. above the platform. The screws carry a strong cross-head *F*, which can be raised or lowered by two nuts. The screws and cross-head are not connected with the platform until the specimen makes the connection. The cross-head receives the fixtures for applying strains of all kinds to specimens of every shape. For tensile strains the holders which grasp the lower end of the specimen are attached to the top of the cross-head. The lower ends of the screws *E* are attached to the short arms of a massive forked lever, which is beneath the floor, and has its fulcra supported by the bed-plate which forms the foundation of the scale. The long arm of this lever is coupled to the fulcrum of a short lever *H*, which is so suspended from a longer lever *G* that the two levers form a differential system. The fulcrum of lever *G* is raised or lowered by a hydraulic jack *N* fixed in a cast-iron frame *O*, which rests on the scale foundation. In later machines than that represented, a screw is substituted for the jack, the nut of the screw being supported by the frame *O*. This nut is worked by a hand-wheel through a system of toothed wheels. The connections between the lever *G* and the screws which carry the cross-head are so arranged that by depressing the longer free arm of *G* the cross-head is pulled downward, and by raising the fulcrum of *G* the same result is produced. A rod *K* is suspended from the end of the longer arm of the lever *G*, to which plates and pans are attached to receive weights of various values. The lower end of the rod *K* is provided with a piston, which moves

in a large cylindrical vessel containing oil and serving to prevent a too rapid fall of the loaded end of the lever. It is evident that if one end of a specimen—a rod of iron, for instance—be attached to the frame D above the cross-head F, and the other end be attached to the cross-head, the specimen may be stretched by bearing down the end of the straining lever G, for the cross-head will thereby be pulled downward. The arms of the levers are so proportioned that one pound applied at M or L on rod K will exert a strain of 120 lbs. on the specimen; so a strain of 100,000 lbs. will be exerted by the application of 800 lbs. at K. The specimen can also be strained by weighting the rod K so heavily that it will be held down, and then, by working the nut of the screw or the handle of the hydraulic jack, either by hand or power, the fulcrum will be raised, and the cross-head pulled downward with a force increasing as gradually as may be desired. As the specimen is suspended from the frame on the platform of the scale, any stress with which it is pulled will be indicated at the weigh-beam B, and can thus be accurately weighed.



4123.

A full description of this testing machine (with drawings), and also of the ingenious electro-magnetic automatic registering device used with it, will be found in "Report of Chief of Ordnance U. S. A." for 1878.

The Greenwood & Batley Testing Machine, constructed by Messrs. Greenwood & Batley of Leeds, England, is represented in Fig. 4123. It is constructed for either tensile, compressive, or bending tests, its maximum load being 100,000 lbs. (or almost 45 tons), and can exert this either in direct tension or direct compression, or at the centre of any beam up to 48 in. between supports, while either for tension or compression it will take in a piece of a clear length of about 75 in. The principle adopted in the machine is that of Mr. Kirkaldy (whose machines have also been made by the same makers), which he has now worked successfully for so long—the principle, namely, of determining the load by a weight acting through a system of levers, and of applying the load by a hydraulic ram. $A\ A$ are two steel forks carrying (in the case shown) collar-dies in which lies the piece to be tested. The pull is transmitted through the two pins G and C, by the former to the steelyard and weight, by the latter to the ram. The pin G passes through a cross-head, which carries four nuts for the four screws D, the front ends of which are connected to the head of the ram E, which is supplied with water by a pump P placed near the other end of the machine. The outer ends of the screws D are fitted with pinions into which gears a spur-wheel (concentric with the ram), which can be worked by a pinion through the hand-wheel F, and in this way the distance between the forks $A\ A$ is adjusted to suit the length of the test-bar.

The pin G is placed in a cast-iron block which embraces the two main pull-bars R, which transfer the pull to knife-edges on the knee-lever T, of which the fulcrum is at L. The downward pressure on the outer end of T passes direct, through the strut-pieces shown, to knife-edges on the steelyard N, on which is a movable weight which can be run out and in by the hand-wheel O and the spur-gearing behind it. The upward component of the pressure on T is taken by two knife-edged struts M. The maximum leverage is 100 to 1, and the maximum weight is therefore 1,000 lbs., which is divided into 20 parts of 50 lbs. each, the truck and suspending rod being adjusted to weigh 50 lbs. exactly. In this way the hydraulic pressure is transmitted to the piece through the screws D, the cross-head, and the pin G, while the pull of the weight passes to the piece through the lever T, the bars H, and the pin G. The use of the weight, of course, renders it unnecessary to consider the frictional resistances of the ram or the cross-head truck, the pull on the piece being simply that due to the load with its proper leverage, which can be read off at once on the scale upon the steelyard. The machine was tested before it was used in order to see whether this was perfectly accurate, or whether there was any sensible frictional resistance to the motion of the knife-edges. For this purpose a load of 1,000 lbs. was made to act (through knife-edges) with a direct pull on the pin G, the clip A being removed. This being balanced by a standard 10-lb. weight at the end of the steelyard, it was found that an addition to the latter of 33 grains was sufficient to start the steelyard down, moving with it, of course, all the parts of the machine which in ordinary work lie between the test-piece and the dead weight. This corresponds only to about a pound per ton.

The Riehlé Testing Machine.—A variety of forms of testing machines are built by Messrs. Riehlé

Brothers of Philadelphia, an example of which is given in Fig. 4124. It consists of a weigh-beam, accurately made and poised upon knife-edges. At its outer end it sustains a scale-pan upon which weights are placed. Intermediate weights are measured by a poise, not shown in the engraving, which traverses the beam, the latter being divided into parts of 10 lbs. each, similarly to the steelyard balance. The specimen is secured at the upper end by wedges or clamps, in a strong collar which is hung from two knife-edges, one on each side of the knife-edge which carries the scale-beam. These knife-edges are placed at slightly different distances from the beam-support, thus making the latter a "differential lever," and permitting the measurement of a great strain without the use of heavy weights or multiple levers. A similar collar below takes the lower end of the specimen to be tested. It is secured to the head of a hydraulic press which is placed within the lower part of the frame of the machine. A small pump, worked by a hand-lever, is used to force oil into the press. The breaking force is thus applied from below, and is measured upon the lever above.

4124.

Emery's Testing Machine.—This machine was constructed by Mr. A. H. Emery, C. E., for the use of the United States Board appointed to test iron, steel, and other metals. It was completed in 1878, and is described by Mr. A. L. Holley as follows: "The machine consists of a double-acting straining cylinder and ram on a carriage at one end, and a movable weighing apparatus at the other end. The two are connected by a pair of 6-in. screws 48 ft. long. Nuts driven by shafting move the straining cylinder to different places on the screws, so as to test long or short specimens. The weighing apparatus has already been described in print as a reversed hydrostatic press, having diaphragms instead of pistons. The load is transferred, by means of a fluid (alcohol and glycerine), by a series of large diaphragms to a series of small ones, and finally to a system of scale-beams. Thus a weight of 800,000 lbs., acting through an inconceivably small space, finally moves a finely-graduated indicator at the rate of one-hundredth of an inch per pound. It is allowed to move through a space of 2 in., and is kept balanced by weights mechanically placed quickly on or off the scale-beam. One pound, in moving the indicator one-hundredth of an inch, moves the platform against which the load presses $\frac{1}{1,000,000}$ of an inch. The whole arrangement of the scale-beams, the adding and removing of weights, and the fast or slow but always steady application of pressure, are ingenious and convenient in the highest degree. By means of universal joints, the pressure-pipes are always connected to the straining cylinder, etc., whatever their positions. The steam-pump and the accumulator have cylinders and weights, respectively for high and low pressures, and the machine receives pressure without pulsation, from the accumulator only, when testing. The finished metal in the machine weighs 175,000 lbs., and includes pieces of 14,000 lbs. down to those of which 250,000 would weigh 1 lb. The hydrostatic weighing platform of the machine was tested to 1,500,000 lbs.; but so perfectly frictionless is it that a horse-hair under a breaking strain of 1 lb. had to move 24,000 lbs. of metal. The workmanship is also remarkable. The 6-in. screws, 48 ft. long, were fitted to gauges within one-thousandth of an inch in diameter throughout their length, and similar accuracy maintained in other parts."

4125.

See paper on "The U. S. Testing Machine at Watertown Arsenal," by A. L. Holley, C. E., in "Transactions of the American Institute of Mining Engineers," 1879.

Gill's Testing Machine.—Figs. 4125 and 4126 represent a testing machine designed and manufactured by Mr. John L. Gill, Jr., of Pittsburgh, Pa. Fig. 4126 shows the machine as arranged for making tests of transverse strength, the lower portion of the apparatus being shown in section. The strain is applied by means of a screw operated by gearing. Hand- or steam-power may be used for the purpose. The change from one to the other may be made instantaneously, by means of the hand-lever shown at the right of the main column of the machine in Fig. 4125. This lever operates through a set of friction-cams, and causes the screw to run upward or downward at pleasure. The weighing is done by means of three beams, coupled in the manner shown. The central beam is graduated for two poises, one upon the upper and the other upon the lower edge. The smaller poise

registers up to 1,000 lbs., and the upper from 1,000 to 10,000. A suspender-rod at the left carries the weights, which are of 10,000 lbs. each. The coincidence of the line of strain with the central line of the specimen is accomplished by making the weighing head, which transmits the strain from the specimen to the knife-edges of the large beam, run in guides both above and below. To do this, the top and bottom of the head are both made cylindrical, and fit the guides on the main column of the machine. To secure truth in all the parts, the two guides in which the weighing head moves, and the inside of the sleeve through which the pulling screw is worked, are bored out with the same boring bar and at the same time, thus insuring that their axes are the same. With weighing head and screw both working in the same straight line, it is evident that there is no tendency to bend the specimen. These machines will test specimens by tension up to 1¼ in. in diameter, and in length up to 18 in. This great length is very desirable, as it has been found that short test-pieces do not give a correct indication of the strength of the material. When used for transverse tests, it will take in specimens from 1 in. square and 12 in. long to pieces 5 in. wide by 8 in. deep and 43 in. long, which is the size of the piece of timber represented in Fig. 4126.

4126.

Thurston's Autographic-Recording Testing Machine, devised by Prof. R. H. Thurston, is represented in Fig. 4127. Two strong wrenches are carried by the A-frames, and depend from axes which are both in the same line, but which are not connected with each other. The arm of one of these wrenches carries a weight at its lower end. The other arm is designed to be moved by hand in the smaller machines and by a worm-gear in larger ones. The heads of the wrenches are fitted to take the head on the end of the test-pieces, which are usually given the form shown in Fig. 4128. A guide-curve, of such form that its ordinates are precisely proportional to the torsional moments exerted by the weighted arm while moving up an arc to which the corresponding abscissas of the curve are proportional, is secured to the frame next the weighted arm. The pencil-holder is carried on this arm; and as the latter is forced out of the vertical position, the pencil is pushed forward by the guide-curve, its movement being thus made proportional to the force which, transmitted through the test-piece, produces deflection of the weighted arm. The guide-curve is a curve of sines. The other arm carries the cylinder upon which the paper receiving the record is clamped, and the pencil makes its mark on the table thus provided. This table having a motion, relatively to the pencil, which is precisely the angular relative motion of the two extremities of the test-piece, the curve described upon the paper is always of such form that the ordinate of any point measures the amount of the distortion which the force produces.

4127.

METHODS OF MAKING TESTS.—*For Tensile Stress.*—1. The machine itself should be tested to determine whether its weighing apparatus is accurate, and whether it is so made and adjusted that in the test of a properly made specimen the line of strain of the testing machine is absolutely in line with the axis of the specimen.

2. The specimen should be so shaped that it will

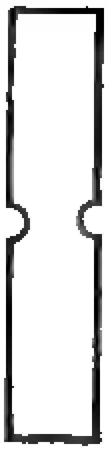
4128.

not give an incorrect record of the strength. Under no circumstances should the test of a piece shaped as in Fig. 4129 (a short specimen) be relied upon. No accurate measurement can be made of its extension before rupture, as a means of comparison of ductility, a quality the knowledge of which is quite as important as that of absolute strength. With short specimens, also, two pieces of different materials may give like results, while long pieces of the same materials may give different results. There is no standard shape for short specimens, no standard relation between the strength of a short specimen and that of a long one, and the test of a short specimen shows the least strength of the material and not its greatest. The piece should be of uniform minimum section for several inches of its length, as shown in Fig. 4130. Mr. William Kent, M. E., in his "Essay on Strength of Materials" (New York, 1879), from which the suggestions here given are taken, recommends "5 in. in length between the extreme points between which measurements of extension

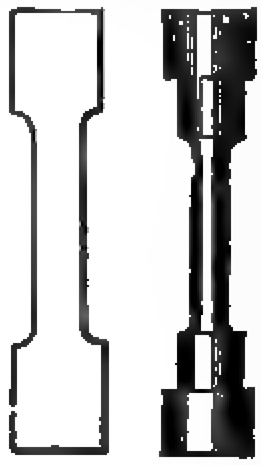
are made for the standard size of specimens, as being the most convenient length for the testing machines now most in use, for calculation of extension in per cent. of length, and for comparison of results with those of other experimenters."

3. Regard must be had to the time occupied in making tests of certain materials. When wrought iron and soft steel can be made to show a higher apparent strength by keeping them under strain for a great length of time, it is well to test them as rapidly as possible to obtain their minimum strength; and in accepting results of tests of these metals from interested parties, it is well to know what length of time has been devoted to the experiments.

4129.



4130.



4. Accurate measures should be made of the extension under each successive increment of load, in order to determine all the properties of the material, other than its mere absolute tensile strength, which make it valuable in construction.

For Compressive Stress.—A standard size of specimen for compressive tests, and a standard limit of compression assumed equivalent to fracture, have never been agreed upon. Mr. Kent proposes "a cylinder 1 in. in length and 1/2 sq. in. in sectional area, or 0.798 in. diameter; and for the limit of compression equivalent to fracture, 10 per cent. of the original length. In making experiments upon compressive strength, even greater care is required than in experiments on tensile strength. In tensile tests the tendency of a ductile specimen is always to pull into the line of strain, and this to some extent (but not entirely) corrects the error caused by wrongly placing the piece in the testing machine. In compressive tests the tendency is just the reverse: the effect of a push is always to cause the piece to tend to bend out of the line of strain; and this can only be prevented by having the line of strain pass exactly through the axis of the specimen. The test specimen should, therefore, be placed in the machine with the utmost accuracy; care should be taken that the bearing of the piece on the compression-blocks is a true one, and that in pulling or pushing together the compression-blocks they shall have no tendency to move sidewise or in any other direction than that of the line of strain.

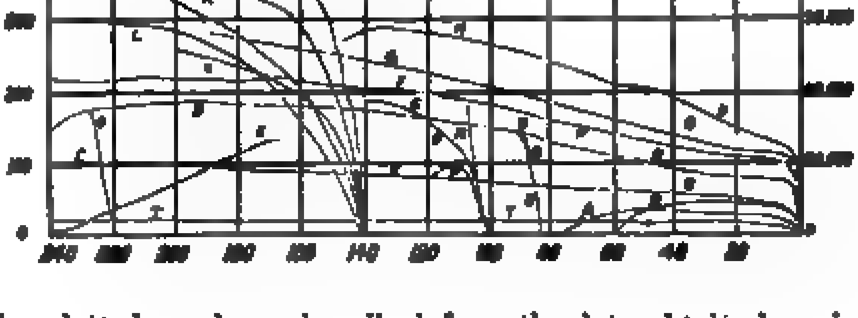
For Transverse Stress.—These tests are in general much more easily made than tests for either tensile or compressive stress. An elaborate testing machine is not necessary. The bar or beam to be tested is placed on two supports which are at a measured distance apart and perfectly level. Weights are applied to the middle of the piece until it breaks. Steel rollers are frequently used for supports, moving on a horizontal plane and kept at a constant distance apart during the tests. The use of rollers prevents the error due to friction of the bar upon the fixed supports.

For Shearing Stress.—For testing the transverse shearing strength of bolts and rivets, the use of double shearing plates is probably the best method. The plates are made of hardened steel, and the holes drilled in them are just large enough to allow the bolt to enter with a sliding fit. The best thickness of the plates or the relation of thickness to the diameter of the holes would have to be determined by experiment before the proper standard could be fixed, as it has been found that the thickness of the bearing has an influence upon the results. As it is not entirely certain that the resistance of various sections of the same material to shearing stress is exactly proportional to the area of section, experiments to determine the relation of shearing resistance to area of section, and to determine the best size and shape for a standard test specimen, are needed, in order that the results obtained by different experimenters may be compared

For Torsional Stress.—The method of making tests for torsional stress is explained in the description of Prof. Thurston's testing machine on page 873. The results obtained are referred to in the following paragraph.

STRAIN DIAGRAMS are graphic representations of results of tests, and are made by plotting the figures of stress and elongation obtained. Each curve is a complete record of all the properties of the material which can be determined by test. The perpendicular distance of any point of the curve from the base-line represents the applied stress per square inch. The horizontal distance from the vertical initial line represents the corresponding extension. That point of each curve at which it first bends toward one side indicates its elastic limit. The inclination of the initial portion of the curve to the vertical initial line measures the stiffness within the elastic limit or coefficient of elasticity. This method of representing results—which is now used by all scientific experimenters on

4131.



the strength of materials—may either be plotted as above described from the data obtained, or in Prof. Thurston's machine it is automatically made by a pencil governed by the apparatus itself. A strain diagram as produced by Thurston's machine is represented in Fig. 4131. The line *A* is

that of zinc. The concave form at the commencement indicates its inelastic nature, its slight altitude shows its weakness, and, breaking at 63°, it is shown to lack ductility. Tin, T, is vastly more ductile, but is still less tenacious. B and C are the diagrams given by cast and forged copper, the latter twisting 800°, and its fibres stretching to three times their original length. Cast copper is comparatively weak and brittle. Wrought iron gives the strain diagram D. It indicates the elasticity of the metal, its ductility, and its strength. The elastic limit is plainly indicated. The concavity of the initial portion of the line indicates some internal strain, and the horizontal portion immediately above the elastic limit shows that the metal was "seamy" and not perfectly homogeneous. The lines e and O are "elasticity lines." They differ slightly in direction from the initial portion of the diagram, confirming the previously indicated presence of internal strain. E is the terminal portion of the diagram of a soft ductile iron. F is that given by a very strong and ductile and exceptionally homogeneous iron, a very smooth and symmetrical curve. G is a soft Bessemer steel. H is somewhat harder, the one containing 0.4 and the other 0.6 per cent. of carbon. I and J are tool-steels containing 1 per cent. of carbon. K is medium, L spring, and M double shear steel. N and P are obtained from white and gray cast iron. One is stiff, hard, and brittle, the other weaker, soft, and comparatively tough. O is a malleableized cast iron made from N, it has lost no strength, and has gained considerable ductility. Strain diagrams may be produced by plotting data obtained by observation in the usual manner and similarly interpreted.

THERMO-ELECTRIC BATTERY. See Electro-Galvanic and Thermic Batteries.

THERMOMETER. An instrument for measuring temperatures. It is formed of two or more different substances, the volumes of which expand and contract to different extents when they are simultaneously exposed to the same differences in intensity of heat.

Construction of the Mercurial Thermometer.—The tube of the thermometer should be of uniform calibre throughout its whole interior. To ascertain whether this is the case, a short column of mercury is introduced into the tube; and if its length remains the same when it is moved throughout the length of the tube, we may be sure that the tube has a uniform bore, and hence that equal amounts of expansion of the mercury will cause equal additions to the length of the mercurial column in the tube. Since tubes of uniform bore are very rare, it is generally necessary to calibrate the tube before its graduation. This is done by etching on the tube a scale of equal parts, and then, from observations on the different lengths occupied by a column of mercury which is made to pass through the tube, forming a table which gives the temperatures corresponding to the arbitrary divisions on the tube. A bulb is now blown on the tube, and this bulb and a portion of the tube are filled with mercury as follows. The air in the bulb is heated while the open end of the tube dips into mercury. The heat having been withdrawn, the air in the bulb contracts and the mercury rises in the tube and partly fills the bulb. To the open end of the tube a funnel containing mercury is adapted, and the mercury in the bulb is boiled and thus expels all air and moisture from the instrument, which on cooling necessarily fills completely with mercury. The bulb is now placed in some fluid heated to a few degrees above the highest temperature which the thermometer is intended to measure, and when the mercury ceases to overflow, the open end of the tube is sealed with a blow-pipe flame. In order to graduate the instrument, the bulb and part of the tube are surrounded with melting ice, and when the top of the mercury column has remained some time stationary, its position is marked by means of a line, or a note is made of this position, referred to the arbitrary scale etched on the tube. The point on the thermometer determined as above is designated as 0°, or zero degree, on the thermometers known as centigrade (Celsius) and Réaumur, and as 32° on the Fahrenheit system of graduation. To determine a higher point on the thermometer, the instrument is placed in the interior of a metallic vessel with double walls, between which circulates the steam from water boiling in the bottom of the vessel. When the top of the mercury column in the thermometer has become stationary, its position is marked on the tube. The boiling-point of water is constant at the same atmospheric pressure; and when the barometric column has a height of 29.922 inches or 760 millimetres, the boiling-point of water is designated as 100° on the centigrade thermometer, 212° on the Fahrenheit, and 80° on the Réaumur. Hence, between the melting-point of ice and the boiling-point of water there are 100 equal degrees in the centigrade graduation, 180 in the Fahrenheit, and 80 in the Réaumur. To convert the indications of one of these thermometers into those of the other two, we have the following formula, in which F, C, and R denote equivalent temperatures expressed in degrees of Fahrenheit, centigrade, and Réaumur respectively: $F = \frac{9}{5} C + 32 = \frac{9}{4} R + 32$; $C = \frac{5}{4} R = \frac{5}{9} (F - 32)$; $R = \frac{4}{5} C = \frac{4}{9} (F - 32)$. Fig. 4132 shows a thermometer graduated according to the three systems.

4132.

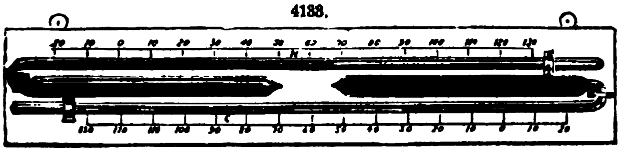
A few weeks after a thermometer has been made and graduated, it may be observed that the mercury will not quite descend to the melting-point of ice when the instrument is immersed in pounded ice. It has been found that this "elevation of the zero-point," as it is called, goes on gradually for about two years after the thermometer has been constructed, and at the expiration of that period the readings may all be too low by nearly a degree; hence it is necessary either to add the proper correction to the readings of the thermometer, or to slide down and refix the scale to which the thermometer is attached, so that it will read accurately. Alcohol, commonly used where temperatures much below 0° F are to be observed, is liable at such range to much variation, although it does not freeze even at −132° F.; and Capt. Parry, in his arctic voyages, observed differences of full 10° C. between alcohol thermometers by the best makers.

Self-recording Thermometers.—Various instruments have been invented which record the indica-

tions of the thermometer. They may be divided into two classes, those which record only the maximum and the minimum of the temperatures occurring in any definite period, and those which produce continuous records.

In the first class may be mentioned the two following instruments. An ordinary mercurial thermometer has its tube constricted to a thin passage at some point between its bulb and the beginning of its scale. This thermometer is placed in a horizontal position, and then as long as an increase of temperature takes place small portions of the mercury will go in a series of jumps across the constricted passage; but on a fall of temperature the mercury contracts in the portion of the thermometer below the constriction, leaving a column of mercury above it. The upper end of the latter column marks the highest temperature reached during the time of exposure. To readjust this instrument, the mercury is sent into the vacant space below the constriction by swinging the instrument. Fig. 4133 shows this "maximum thermometer," the invention of which has been claimed by several

4133.



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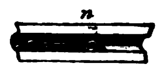


persons. The "minimum thermometer" of Rutherford, which is generally used, is made of alcohol contained in the ordinary glass bulb and tube. In the column of alcohol is a small index made of black glass and shown at *n*, Fig. 4134. This piece of glass is brought up to the end of the fluid column by inclining the instrument. The thermometer is then placed in a horizontal position, and as the temperature falls the top of the liquid column during its retraction carries the glass index with it, and leaves it at the point which indicates the minimum temperature reached during the exposure of the instrument.

The thermometers of the second class give continuous records, either by causing a tracer attached to some simple or compound metallic bar to mark a continuous line on a cylinder which revolves once in 24 hours, or by the aid of photography a continuous impression of the image of the top of a thermometric column is obtained by illuminating a thermometer placed in front of the lens of a camera, while at the back of the camera is a sensitized plate on which the image is formed. The plate traverses athwart the beam issuing from the lens by a known distance each hour.

Differential Thermometer.—This is a modification of the air thermometer, in which two large glass bulbs above are connected by a glass tube bent twice at right angles; the horizontal and parts of the upright tubes are filled in the common form with a colored liquid, which is depressed on either side as the corresponding bulb is more heated; thus the instrument indicates differences of the temperatures to which the two bulbs may be exposed. It is very sensitive; and by a scale the results it affords are comparable with each other.*

THRESHING MACHINE. See Agricultural Machinery.

THROSTLE. See Cotton-spinning Machinery.

TILE-MAKING MACHINE. See Brick-making Machinery.

TIP-STRETCHER. See Hat-making Machinery.

TORPEDO. A submarine mine for the destruction of vessels, bridges, etc. Torpedoes are generally classed as defensive and offensive. The history of the torpedo as a weapon of war is fully detailed in "Submarine Warfare," Barnes, New York, 1874; also in a lecture on "Submarine Boats," Barber, Newport Torpedo Station, 1875. See also the "American Cyclopædia."

Defensive Torpedoes.—The object of submarine torpedoes placed in a channel or roadway is to destroy an enemy's vessels, or to detain a hostile fleet under fire of land batteries. They were extensively used during the civil war in this country, and in the Franco-German war of 1870–'71 they protected the German coasts against the French fleets. The construction of many ingenious forms of torpedo used during the former war will be found described and illustrated in the *Scientific American*, vi., 161; ix., 164, 229, 388; x., 390; xi., 21, 228.

The modern system of moored torpedoes is divided into four classes, namely: electrical, electro-contact, electro-mechanical, and mechanical. Descriptions of modern apparatus in connection with these torpedoes, modes of defending harbors, etc., will be found in a series of articles entitled "Notes on Torpedoes," in *Engineering*, xxi., 15, *et seq.*

I. Electrical Torpedoes.—In this class of submarine mines, which rank first from the variety of their use, a wrought-iron case is employed for containing the explosive, usually guncotton. Attached to this case, and in electrical connection with the fuses for igniting the charge, is a self-acting circuit-closing apparatus inclosed in a buoyant vessel, which is secured to the mine by a Bessemer-steel wire rope. The torpedoes are moored in electrical connection with the shore, and, in addition to the advantage of being rendered safe for the passage of a friendly vessel, may be fired either by contact or by observation, the position of a hostile vessel relative to any particular mine being ascertained by a camera obscura, or by means of a telescopic arc provided for the purpose. The advantage of this arrangement is that both systems of firing are in operation at one and the same time.

A number of ingenious circuit-closers have been devised for this class of torpedoes. the simplest of which are those contrived by Capt. C. A. McEvoy of the British service. One of Capt. McEvoy's contrivances consists of a small ebonite cylinder fitted with a metallic cap, to which is attached one pole of the battery. The cylinder is partly filled with mercury, which is in electrical contact with a

* From the "American Cyclopædia."

metal pin passing through the base of the ebonite cylinder and in connection with the other pole of the battery. The circuit is completed by a blow jolting the mercury into contact with the metal cap.

Fig. 4185 represents an Austrian electrical torpedo, in which *a* is the anchor; *b*, a buoyant case containing the charge, fuse, and circuit-closing apparatus; and *d*, the electric cable extending to the shore.

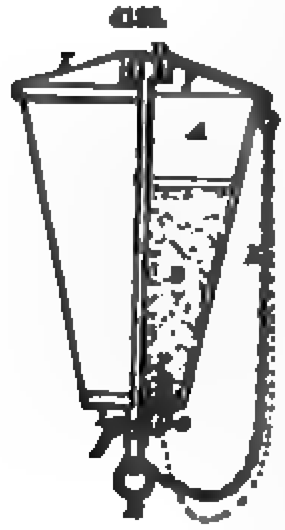
4185.

II. Electro-Contact Torpedoes.—These usually consist of a pear-shaped vessel inclosing an air-tight chamber, which, in addition to supplying the requisite buoyancy, contains the charge of explosive employed. Into this chamber is also inserted the circuit-closing apparatus, to which is attached a bursting shell containing the fuses and charge. They are moored in electrical connection with the shore, and, like the more elaborate class previously described, may be rendered safe at the will of the operators in charge of the station; but, as their name implies, they can only be fired by a vessel or some other hard substance striking them with sufficient force to close their electrical circuit.

III. Electro-Mechanical Torpedoes.—These are similar in form to the electro-contact mines, but, having no electrical connection with the shore, cannot be rendered safe for the passage of friendly vessels, and consequently are not available for the defense of a navigable channel. The advantages claimed by their inventors for this class of torpedoes, over the purely mechanical ones, are the possibility of their being recovered when no longer required for service, and the facilities which they afford for blockading purposes.

IV. Mechanical Torpedoes.—In this class of torpedoes the explosion of the charge is brought about by purely mechanical means. The mechanism consists of a buoyant case containing the requisite charge of guncotton or powder, and fitted with a self-acting primer for igniting the charge when the torpedo is struck by a passing vessel. Singer's torpedo, which was extensively used by the Confederate forces during the civil war, is represented in Fig. 4186. It consists of a conical iron vessel moored beneath the surface of the water. The upper portion *A* is an air-chamber. *B* is a compartment containing the charge. Through the vessel passes an iron bar *C*, having a ring *D* at its upper end, through which the rope for lowering the torpedo into position is passed. At the lower end of this bar is another eye, to which is secured the mooring rope. Ignition is effected by means of a friction-tube *F*, made water-tight by a soldered copper disk *H*. This disk, though thick enough to exclude water, is sufficiently thin to allow a good pull to act effectually through it on the friction-tube. This is done by means of a loose metal cover *I* fitting on the top of the apparatus, and so arranged as to be thrown off when the case is pushed on one side by the contact of a passing vessel. This metal cover is connected to the friction-tube by a chain *K*, and directly its weight comes on this the tube is pulled, and the mine fired. In order to guard against an accidental explosion while placing the mine in position, a brass safety-pin *L*, fitting into a hole in the lower portion of the bar *C*, is so arranged as to pass through a link in the chain, so that if the top falls off the force of the jerk is taken up by this pin, and not by the ring *O* of the friction-tube. A line attached to this pin enables it to be removed after the torpedo is adjusted in place.

4186.



Experiments on Defensive Torpedoes.—Among the most important experiments which have been conducted on torpedoes for harbor defense are two series made for the British Government. The first was made on the Medway in December, 1870, with a view to ascertain how near submerged charges of 500 lbs. of compressed guncotton could be moored one to another without danger of the explosion of one injuring neighboring charges. It was determined that the closest proximity in which buoyant torpedoes may be moored one to another in safety is 180 ft., while the necessary distance between ground mines of a like charge is even greater, ranging at about 200 ft., the distance varying slightly with the depth of water under which they are placed. The second series of experiments was instituted in November, 1875, to determine the probable range at which a submarine ground charge of 500 lbs. of guncotton would demolish a vessel endeavoring to pass its station. The Oberon, an iron paddle-wheel vessel of 800 tons burden, was fitted with sides and bottom corresponding to those of the iron-clad Hercules, and was used as a target. The following is a summary of the experiments: Charge of 500 lbs. of guncotton, equal to 2,000 lbs. of gunpowder, resting on ground in 48 ft. of water. 1st experiment—exploded at 100 ft. horizontal distance from starboard side of ship. No effect. 2d experiment—at 80 ft. Effect slight. 3d experiment—at 60 ft. Effect still inconsiderable. 4th experiment—48 ft. Engines severely injured and condenser broken, doubtful if vessel could have proceeded on her course. 5th experiment—attack transferred to port side. The depth of water was here found to be 72 ft., so that the charge was suspended at a distance of 24 ft. from the bottom, and 30 ft. horizontally from ship. Effect much less than on previous trial, showing the disadvantage of buoyant torpedoes as compared with ground charges. 6th experiment—attack on starboard side resumed: torpedo moored 30 ft. horizontally from vessel. Water-casks and ship's thwart-plates affected, and serious leakage and injury occasioned. 7th experiment—charge placed vertically beneath vessel. Shock tremendous, breaking ship's back and leaving her a complete wreck.

A detailed account of the Oberon experiments appears in *Engineering*, xviii., 126 *et seq.*

A large number of tests of torpedoes have been made by Gen. Abbott at the U. S. Army Torpedo School at Willett's Point, N. Y. The results of these, however, are kept secret. The explosive force of the torpedo is measured by means of the compressing of lead bars one inch in thickness. The force exerted vertically or upward has been found to be greatest, and in some cases to be suffi-

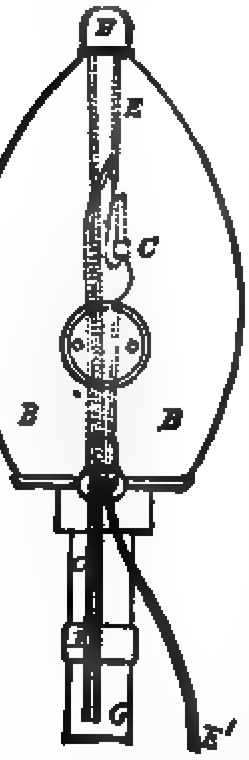
cient to compress the bars to fully one-third of their length. (See *Scientific American Supplement*, No. 189.)

Defense against Moored Torpedoes.—There are four principal methods of forcing a passage through a network of submarine torpedoes: first, the sending down of divers to search for and sever the connecting cables; second, the sending out of small craft under cover of darkness to grapple for and raise the torpedoes bodily from their anchorage, using small charges of guncotton to sever the cables; third, the projecting of a guard of steel wire or other materials some 40 or 50 ft. in front of the vessel's bow, supporting it if necessary with buoys, whereby the circuit-closer would be struck and the mine exploded before the vessel was near enough to receive anything more than a severe shock; and fourth, the use of forked "torpedo-catchers" attached to the bow, and extending as before some 50 ft. ahead. These simply grapple a buoyant torpedo and tear it from its anchorage. To this class belongs an apparatus of English invention, which consists in a couple of booms 30 ft. in length projecting from the bow of the ship. Across the submerged ends is fixed a horizontal beam 38 ft. long, having a zigzag arrangement of iron rods in the form of a W, the idea being that the open space of each V of the series, as it is pushed through the water, will inclose the torpedo fastenings and lead them to a point at the bottom which is fitted with a scissor contrivance, the blades of which are worked by levers in connection with a capstan on board. The searcher has a sweep of 50 ft. A net supported by the bowsprit receives the liberated torpedo and prevents its exploding against the operating craft.

OFFENSIVE TORPEDOES are sent from the shore to destroy an enemy's vessel, or from shipboard during action to blow up an antagonist. They may be divided into three classes—spar torpedoes, towing torpedoes, and automatic torpedoes.

I. SPAR TORPEDOES are attached to the ends of long spars or booms which are projected from the bow or side of the attacking vessel. The torpedo on striking the enemy is exploded either by concussion or by an electric current. A description of the torpedoes of this class used during the civil war will be found in a paper on "Spar-Torpedo Warfare," read by A. S. Woolley before the British Institution of Naval Architects, 1875 (see *Engineering*, xix., 303).

4137.



One of the latest and simplest forms of spar torpedo is that devised by Capt. McEvoy, and represented in Fig. 4137. It is constructed with a tube running vertically through its centre, through which the conducting wires are led to the circuit-closing mechanism. *B B* is the torpedo case, which may be constructed of either copper, Lowmoor iron, or zinc; *C*, the projecting spar to which the torpedo is fixed; *E E'* are two conductors connected with the opposite poles of a voltaic battery; *G* is also a conductor; and *F*, the circuit-closer. The position of the wires within the case, and method of connecting fuse, are indicated by dotted lines. The construction of the circuit-closer is such that when the head is driven in by a blow a dished plate is forced back against the ends of the wires, and electric communication is immediately established with the fuses, which ignite and explode the torpedo. Means are also provided whereby the torpedo can be exploded at the will of the operator. The apparatus is described in detail in *Engineering*, xxv., 127. The torpedoes themselves are simply copper cases containing about 55 lbs. of dynamite.

Spar Locomotive Torpedoes.—These are torpedoes which may be freed from the end of a spar when at a certain distance, say 100 yards, from the vessel attacked, and then pursue their onward course alone. This has been done by placing in the torpedo a reservoir of carbonated water and an acid receptacle. When desired the acid and alkali are mixed, and the carbonic-acid gas generated escapes and actuates a small screw-propeller. Another plan is to form a thread or worm around the torpedo. The torpedo spar is then rapidly revolved, and the torpedo while rotating may be quickly detached, so that it screws its way ahead. None of these plans have proved practically successful. (See *Engineering*, xxv., 208.)

4138.

Experiments with spar torpedoes and details of the vessels in which they are used will be found under "Torpedo Boats" in another portion of this article.

II. TOWING TORPEDOES.—The towing torpedo is attached to a rope and allowed to drag astern of a fast vessel, whose duty it is to move rapidly past the enemy. The course is so directed as to bring the torpedo in contact and explode the charge under his bottom. This is accomplished by skillfully causing the case to dive at the proper moment by the slackening of the tow-rope, and then, by suddenly checking the latter, causing the torpedo to rise and explode. The mode of towing the torpedo is shown in Fig. 4138.

The most effective form of this class of torpedo is the Harvey or "otter" torpedo, which is represented in Fig. 4139. It consists of an external case *A*, of wood iron-bound, inside of which is placed a cubical case of copper, through which passes a brass tube in which is placed the exploding bolt. The inner case has openings above for the introduction of the explosive. In the tube are placed the exploding bolt and priming charge. In the centre of the priming chamber is a brass tube in which the exploding bolt works, and at the bottom of this tube is a steel-pointed anvil, which when the bolt is forced down pierces a capsule and ignites a detonating compound. The charge is from 35 to 100 lbs. of dynamite. *F* and *H* are levers which force down the bolt. *L L* are buoys. A detailed description of this torpedo will be found in *Engineering*, xxiv., 391.

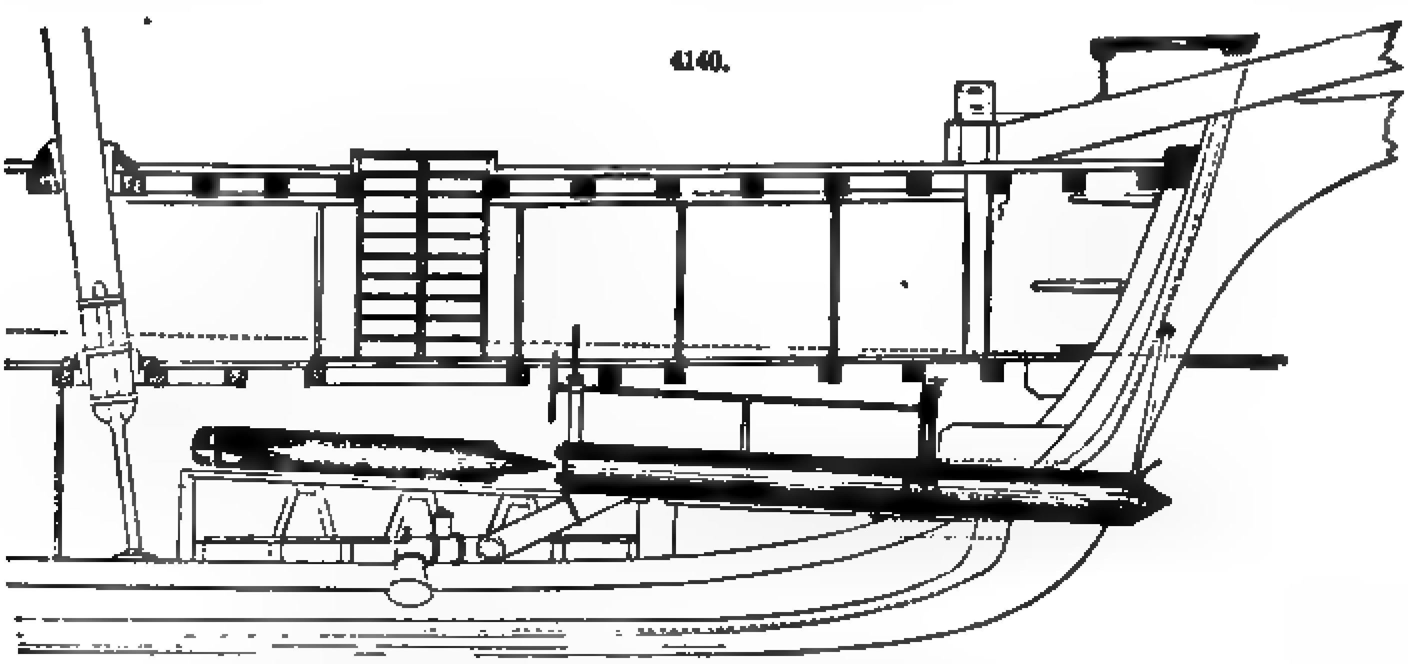
The Barber torpedo is modeled on the Harvey, and claims to be an improvement on its prototype. The long lever-arms are suppressed, and are replaced by six fuses projecting at various angles from the surface of the powder-chamber. The explosion is effected either mechanically by collision, or electrically through the conducting wires forming the core of the towing rope. The torpedo is kept at the required level by means of fins adjusted in the rear of the shell. Buoys are thus dispensed with, and the torpedo is in consequence less easily observed by the enemy.

III. Automatic Torpedoes.—To this class belong those torpedoes which combine vessel and torpedo in one. They carry no crew, and are constructed to travel under water. Three types may be recognized: the fish torpedo, which is entirely self-contained, or, in other words, has its own motive power and cannot be governed after it has once been projected; the Lay torpedo, which carries an engine and has means of generating gas for driving the same, but is directed by electrical wires communicating with ships or shore; and the Ericsson pneumatic torpedo, which is both directed and actuated by a current of compressed air led through tubes to the boat.

The Whitehead Torpedo is the principal form of fish torpedo. The exact details of its construction are kept carefully concealed from manufacturers, but generally it consists of a cigar-shaped vessel, varying from 14 ft. to 19 ft. in length, and from 14 in. to 16 in. in diameter. It is made of specially prepared steel, and is divided into three parts: the head, containing the guncotton and the exploding apparatus; the central part, containing the machinery; and the third or tail part, containing the supply of compressed air for the engines. The motive power is supplied by a small engine of the Brotherhood three-cylinder type, a type which lends itself readily for packing in a cylindrical chamber. The working pressure of the air in the tail is usually about 1,000 lbs. per square inch, and the quantity carried is sufficient to propel the largest-sized torpedo a distance of 220 yards at a speed of 24 knots, or 1,000 yards at a reduced speed of 16 knots. By an arrangement connected with horizontal rudders, the torpedo can be made to run below the surface of the water at any required depth, and keep thereat until the end of the run.

The torpedo can either be projected from a tube by compressed air, or can be launched by hand by simply starting the engine. The former is the method adopted for use from a ship or submarine battery, and is shown in Fig. 4140. The latter is the plan adopted for use from small boats. The launching-tube is passed through the dead-wood of the stem and stern of a vessel; also, if thought advisable, through its sides, at a depth of from 3 to 12 ft., according as the draught of the ship will

4140.



allow. Fig. 4140 represents the launching-tube as fitted to the Austrian vessel Gemse. It is provided at its outer end with a conical door, worked by means of a strap-hinge and a lanyard. Inside of the dead-wood is a gate working vertically by means of gearing; the inner end of the tube is also provided with a door fitted like the others with a water-tight joint; near the inner end of the

tube is a branch pipe connecting with a Kingston valve in the bottom of the vessel. The torpedo is first filled with compressed air, by means of an air-compressing pump in the engine-room, and then set to the depth and to the distance desired, after which the cone containing the charge is secured, and the percussion arrangement properly adjusted. This being done, the torpedo is pushed into the launching-tube, the door behind it closed, and the water admitted from the Kingston valve into the tube, the vertical gate being raised at the same time. The outside conical door can be raised at any time after opening the Kingston valve, and kept open on going into action. The pump in the engine-room supplies air to a reservoir placed in some suitable position in the vessel; and when wishing to discharge the torpedo, communication is opened between the reservoir and an apparatus in the rear end of the launching-tube, driving the torpedo out with great velocity, and starting its engine at the same instant.

The construction of the Whitehead and other "fish" torpedoes is discussed in a lecture "On the Whitehead Torpedo," by Lieut. F. M. Barber, U. S. N., Torpedo Station, Newport, R. I., 1874.

The Lay Torpedo is spindle-shaped, and consists of a shell of boiler iron 28 ft. 3 in. long, divided into four compartments. The forward one, technically known as the nose, contains the charge of explosive material, viz., 300 lbs. of powder or 75 lbs. of dynamite. The second in order contains the motive power, which consists of carbonic-acid gas generated in the usual way by the outpouring of sulphuric acid (from three flasks) on a carbonate. The gas, which has an initial pressure of 40 atmospheres, is conducted from the generating apparatus through iron tubes to the engine, which is fitted up in the fourth compartment. The third section contains a roll of 10 miles of insulated wire, which is paid out from the reel itself, and serves to keep up electrical connection with the firing station. The torpedo is entirely under the control of the electrician, who, by means of a series of contacts, opens or closes certain valves, and thus increases or diminishes the speed and stops or steers the torpedo as circumstances may require. The torpedo is submerged to about four-fifths of its volume, and cleaves its way through the water at an average rate of 10½ knots an hour. It may be fired either by contact or by closing the electric circuit. Its position is always known by the slender guide-poles which project from its upper surface.

The Lay torpedo has been successfully manœuvred at a mile and a half distance from the station from which it was dispatched. For detailed descriptions see *Scientific American*, xxix., 31, xxxiv., 324, and *Scientific American Supplement*, No. 22.

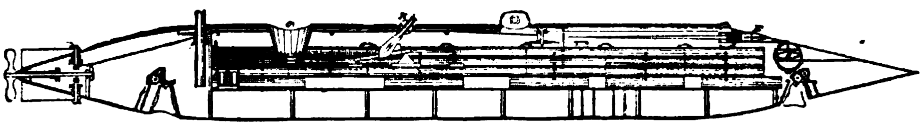
The Ericsson Pneumatic Torpedo has a shell made up partly of wood and partly of iron. It is 13 ft. 6 in. long, and is propelled by pneumatic pressure produced by strong condensing air-pumps erected at the firing stations. The air is led through a stout hose, which is gradually paid out, to the engine situated within the body of the torpedo. This is connected with a double screw whose rotation produces the necessary propulsion. The driving power consists in reality of two screws revolving in opposite directions. This contrivance was adopted in order to neutralize the effect of the water, or back-lash, on the rudder. The depth of immersion varies from 6 ft. to 15 ft., and is attained by setting the "diving pins" at an appropriate angle. The charge consists of 200 lbs. of powder; it is lodged in the nose and fired mechanically. Some ingenious mechanism has been devised by means of which the movements of this machine may be regulated, so that, applying different pressures, the speed may be varied, and the torpedo may be stopped or directed at pleasure. The secret of the arrangements necessary to effect this has not transpired. Owing to the weight and length of the hose, it has not been found practicable to send this torpedo to a distance exceeding a few hundred yards. In the frequent experiments made by the United States Navy, but little success was obtained in steering this torpedo. (See *Scientific American*, xxxi., 390.)

Torpedo Boats.—Vessels especially devised for torpedo warfare may be divided into three classes: 1. Submarine boats; 2. Torpedo launches; 3. Large torpedo vessels.

I. Submarine Boats were the earliest means adopted for attaching torpedoes to the hulls of vessels. David Bushnell, a captain of engineers in the American army during the Revolution, devised a submarine boat to carry a torpedo charged with 150 lbs. of gunpowder, to be attached by a wood-screw to the bottom of an enemy's vessel, and fired by a clockwork fuse. The first actual trial of this invention in 1776, against Lord Howe's flag-ship in New York Harbor, resulted in failure. A full description of Bushnell's boat, and of the principal attempts to construct vessels of this kind, will be found in a lecture on "Submarine Boats," by Lieut. F. M. Barber, U. S. N., published at the U. S. Torpedo Station, Newport, R. I., 1875. Probably the best device of this kind was the so-called Phillips boat built on Lake Michigan in 1851. The vessel used by the inventor was cigar-shaped, 40 ft. long and 4 ft. in greatest diameter. It had many ingenious contrivances for keeping it on an even keel and adjusting its depth under water. It was propelled by a hand propeller, and accomplished a speed of 4½ knots with two men at the cranks.

Fig. 4141, from Lieut. Barber's work, shows the proposed plan of a torpedo boat on the above

4141.



system. The diameter is about one-eighth the length. At *C* is a recess for torpedoes, which are placed in an opening in the cylinder underneath, the cylinder being turned until they pass up through a corresponding aperture. At *H* is a submarine gun working in a ball-and-socket joint. At *E* is a rocket to be fired along the surface of the water, carrying with it a torpedo *F*. The torpedo is pro-

vided with a pair of diving fins, and when the rocket, which carries a large bursting-charge, strikes and explodes, the torpedo dives and bursts under the bottom of the ship attacked.

The Winans submarine boat, built in 1872 for the St. Petersburg Yacht Club, is a cigar-shaped cylinder of steel, 78 metres long and 4.88 metres in diameter. Two propellers, each 7.6 metres in diameter, are used at opposite ends of the boat. The engines work up to 2,000 horse-power.

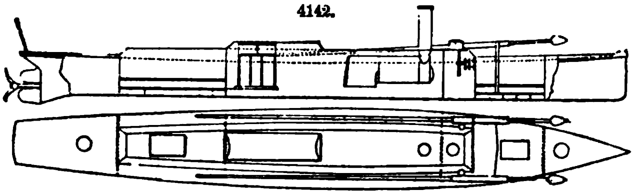
The submarine boat used by the Confederates in the sinking of the U. S. steamer Housatonic off Charleston Harbor was built of boiler iron. She was 35 ft. long, and was manned by a crew of 9 men, 8 of whom worked the propeller by hand. In smooth water she could make about 4 knots per hour.

II. Torpedo Launches.—These are small swift boats designed to approach under cover of the night or of a fog, and destroy a hostile vessel by exploding a spar torpedo against her side, or by the projection of a fish torpedo. The requirements of such craft are: 1, speed; 2, capability of being rapidly manœuvred; 3, perfectly noiseless machinery; 4, sufficient thickness of the steel deck to protect the crew from mitrailleuse fire. There is no mode of torpedo attack so dangerous. But little more than the deck of the boat is visible above the water, and this is rendered difficult to discern by its dull gray color. Actual experiment has shown that a swift launch may run alongside a large vessel despite the closest watch, and that heavy guns are of little or no avail as a means of prevention, owing to the difficulty of hitting so rapidly moving a target. Various methods of defense have been devised, however, to which reference is made farther on.

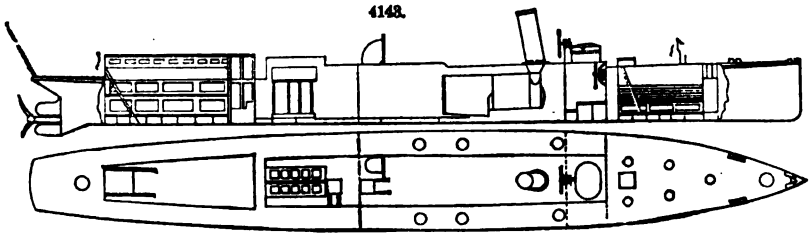
The most improved torpedo launches are those constructed by Messrs. Thorneycroft & Co. of London, England, three forms of which are represented in Figs. 4142, 4143, and 4144.

Fig. 4142 represents the torpedo boat constructed for the Austrian and French Governments. The dimensions are: length, 67 ft.; beam, 8 ft. 6 in.; draught of water, 4 ft. 3 in. They are built of steel plates and angle bars, the armor extending down to the water-line on each side. They are divided into six water-tight compartments, and the spaces fore and aft the machinery are permanently decked. The engines are of the usual inverted double-cylinder, direct-acting type, fitted with a surface condenser and capable of developing 200 indicated horse-power. Air is supplied to the furnace by being forced into an air-tight stoke-hole. The boiler is of steel and of the locomotive type. The fire-box and stays are of copper, and the tubes of drawn brass. The compartments in the stem and stern are for stores, the adjacent ones for the crew, and those amidships for the steersman and the machinery, these being armor-plated. The steering compartment has a hood, provided with narrow slits to enable the helmsman to direct his course. The Austrian boats on a trial for speed made

4142.



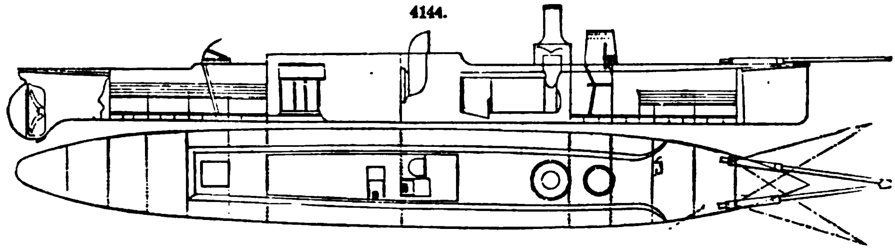
4143.



18.202 knots per hour. The steam-pressure averaged 105 lbs. per square inch, and the vacuum 25¼ in. during the run. The French made 18.025 knots per hour, with a steam-pressure of 108 lbs. and vacuum 25 in.

In February and March, 1877, the French Government made some experiments at Cherbourg with

4144.

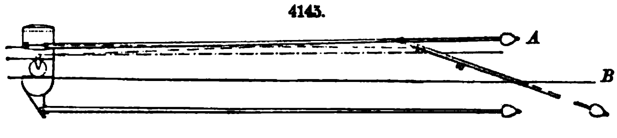


these boats in actual attack upon the Bayonnaise, an old wooden frigate. The method of working the torpedo spars adopted is shown in Fig. 4145, *A* representing the deck-line and *B* the centre-line of the boat. The apparatus consisted of a steel pole about 40 ft. in length, having one end about

6 in. in diameter and solid, and the other about 1½ in. in diameter and hollow; this pole was mounted at its solid end on small pulleys which ran upon two ropes stretched fore and aft of the vessel; the other end, to which the torpedo was attached, was led over a pulley fixed on the bow. Ropes passing over pulleys to a windlass in the after compartment were attached to the inboard end, and by turning the windlass the pole was drawn backward or forward as required. It will be observed that as the pole is drawn forward, the inboard end being constrained to move in a line parallel to the deck, the outer end is depressed in the water, and is so adjusted that when the pole is run out to its full extent the torpedo is depressed to about 8¼ ft. below the water-level. The Bayonnaise was towed at a speed of 6 knots per hour, and the attacking boat approached her at a speed of 14 knots. The torpedo, charged with 33 lbs. of damp guncotton and submerged to a depth of 8¼ ft. below the surface of the water, exploded immediately on striking, tearing an immense hole in the Bayonnaise, so that the latter would have sunk at once had it not been for auxiliary supporting casks. An important result of the French experiment was the discovery that only 90 per cent. of the explosive which might be safely fired at the bow could be fired at the stern, and only 35 per cent. at the side.

Fig. 4143 represents the Lightning type of vessel built for the English Government. The dimensions are: length, 84 ft.; beam, 10 ft. 10 in.; draught of water, 5 ft. The speed is 18 knots. The engines are capable of indicating 350 horse-power. She is armed with Whitehead torpedoes. It will be noted that both this boat and that represented in Fig. 4142 are provided with the Thorneycroft screw. This is so constructed as to prevent the water from being driven out radially from the axis by the centrifugal force. The blades are curved, and it is stated that the curvature varies in such a way "that the inclination of the blade to the axis is greater near the boss than at the tip, on account of the greater amount of centrifugal force impressed on a particle of water near the boss as compared with a particle of water near the tip." The arrangement of the screw abaft the rudder is abandoned in a later type of Thorneycroft boat represented in Fig. 4144, known as the improved "Lightning," and built for the French Government in 1878. The dimensions are: length, 87 ft.; beam, 10 ft. 6 in.; draught, 5 ft. 6 in. The highest speed made by this vessel on the measured mile was 19.423 knots per hour, and on a three hours' run an average of 18.963 knots. The construction of the Thorneycroft launches is described in a lecture "On Torpedo Launches," delivered by Mr. John Donaldson before the Royal United Service Institution, May, 1877.

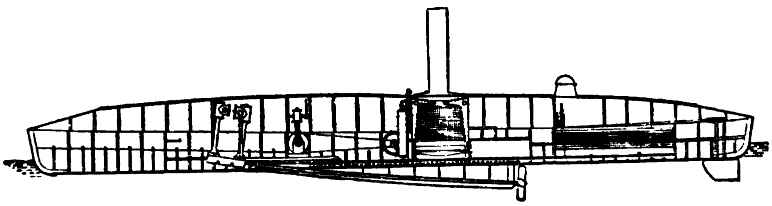
4143.



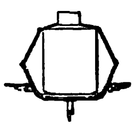
It is worthy of remark that the vessels built for torpedo service by Messrs. Thorneycroft & Co. have not attained the speed of some of their other boats, notably the Gitana, a pleasure yacht constructed for Baroness Rothschild. This vessel, which is 91 ft. long by 13 ft. 6 in. beam, on her trial-run of 1 hour and 48 minutes, averaged 23.89 miles per hour. The boiler-pressure was 100 lbs., vacuum 24 in., horse-power developed about 450, and mean number of revolutions 318 per minute. (See *Engineering*, xxii., 465.) The fastest torpedo launch constructed up to the present time (1879) is that built by Messrs. Yarrow & Co. of Poplar, England, for the British Government. Her length is 86 ft., beam 11 ft., and displacement 27 tons. The cylinders are 13 in. and 22 in. in diameter, and 12 in. stroke. On her official trial this boat accomplished a speed of 21.9 knots per hour. An account of her performances, with indicator diagrams from her engines, appears in *Engineering*, xxviii., 307.

The Herreshoff Torpedo Launch, built for the British Government, is represented in Figs. 4146 and 4147. The dimensions are: length, 59 ft. 6 in., and beam, 7 ft. 6 in. The hull is composite, with timber planking below the water-line and a steel skin above. There is also a steel superstructure covering the machinery and men. Fig. 4147 shows the manner in which the junction is made between the steel upper skin and the timber planking. The engine is compound, having a 6-in. and a 10½-in. cylinder, with 10-in. stroke. The boiler consists of a coil of wrought-iron pipe 2 in. in diameter and about 300 ft. long, this coil forming a kind of combustion-chamber above the grate, which is 4 ft. in diameter. The feed is supplied to the upper end of the coil, and the mixed steam and water escaping from the lower end passes into a separator, where the water is deposited, the steam being then led through a short superheating coil on its way to the engine. As will be seen from Fig. 4146, the engine is placed well forward in the vessel and the shaft runs at an inclination through the bottom of the boat. In order, however, to counteract the effect of running a screw with a steeply inclined shaft, the latter is curved throughout its length, so that the after end is brought nearly horizontal. The shaft is of steel, and is kept to the curve shown by being run in a brass tube which is bent to the desired curve, and which forms a kind of continuous bearing from end to end. The

4146.



4147.



curved tube forming the shaft-bearing is securely fixed inside a double walled copper chamber, which projects below the bottom of the boat, and serves the triple purpose of a support to the shaft, a fixed centre-board or false keel, and a surface condenser. The keel formed by the condenser, being at the centre of the length of the vessel, forms a kind of pivot on which the boat may be turned. The exhaust-steam from the engine enters the condenser near the forward end, and the suction-pipe to the air-pump draws from the after end. The screw is 38 in. in diameter, with 5 ft. pitch, and, as will be seen, is situated more than one-third the length of the vessel from the stern. Owing to its position, the screw is of course always working in solid water. The rudder is balanced. The weight of the boat with stores and torpedoes is 8 tons.

III. Torpedo Vessels.—Appliances for the use of spar, towing, and fish torpedoes form part of the armament of all modern war vessels. A variety of craft have however been constructed especially for torpedo service, and built in a manner and of a size which differentiate them wholly from the torpedo launches. The German torpedo ship Ziethen is 226 ft. long, 28 ft. broad, and 18 ft. 6 in. deep, and is arranged with two long tubes placed parallel to the keel, from which fish torpedoes are projected. (See "Report of Chief Engineer J. W. King, U. S. N., on European Ships of War," Washington, 1877.)

The U. S. torpedo ship Alarm was constructed from plans prepared by Admiral D. D. Porter, U. S. N. Her length is 172 ft., of which 32 ft. is snout or ram, beam 27 ft. 6 in., and draught of water 11 ft. She uses spar torpedoes thrust out from the bow and sides, and also carries a heavy gun and a number of mitrailleuses. A detailed description of this vessel appears in the *Scientific American*, xxxvi., 159.

The Polyphemus, one of the most novel forms of English torpedo vessels, is built of steel and has a convex deck. The convex curvature is continued round her sides some distance below the water-line, after which her sides converge toward the keel, or rather to where her keel should be, in V-shape. The deck rises but 4 ft. 6 in. above the water-line. The vessel is 240 ft. long, 40 ft. broad, and has a load-draught of 20 ft. The engines work up to 5,500 horse-power, and give her a speed of 17 knots. She is provided with a heavy steel ram and means for projecting Whitehead torpedoes.

Captain John Ericsson's torpedo vessel, the Destroyer, has several novel and peculiar features. The bow and stern are exactly alike, terminating in very sharp wedges. The length is 130 ft., depth 11 ft., beam 12 ft., extreme. The rudder is wholly unconnected with the visible part of the stern, being attached to a vertical wrought-iron post welded to a prolongation of the keel, just aft of the propeller. Its upper part is nearly 4 ft. below water-line. The tillers consist of thin plates of iron riveted on opposite sides of the rudder, a few inches from its bottom; they are operated by straight rods connected to the pistons of horizontal hydraulic cylinders of 5 in. diameter attached to the sides of the keel. Accordingly, the steering gear is placed 10 ft. below water-line, while the top of the rudder only reaches within 4 ft. of the water-line. This vessel is so far impregnable that, in attacking bow on, it can defy the opponent's fire, offering absolute protection to the commander and helmsman, as well as protecting the base of the smoke-pipe. The hull is provided with an intermediate curved deck extending from stem to stern, composed of plate-iron strongly ribbed and perfectly water-tight. This intermediate deck sustains a heavy solid armor-plate placed transversely to the line of keel 32 ft. from the bow, inclined at an angle of 45°, and supported on the aft side by a wood backing 4 ft. 6 in. deep at the base. The steering-wheel is applied behind this wood backing, a wire rope extending from its barrel to a four-way cock near the stern, by which water-pressure is admitted alternately to the hydraulic cylinders at the stern, the motion of whose pistons actuates the rudder. The lower division of the vessel is supplied with air for the boiler furnaces by powerful blowers drawing in air from above. During attack the Destroyer is intended to be as deeply immersed in the water as the monitors; but a deck-house or cabin 70 ft. long, composed of plate iron, is riveted water-tight to the upper part of the hull. As this cabin, which has no opening in the sides, virtually forms part of the hull, it would be safe to run with the upper deck considerably below the water-line.

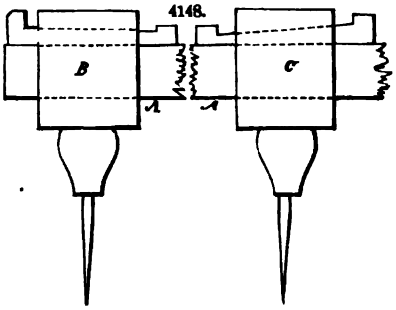
Defense against Offensive Torpedoes.—This is an unsolved problem. The most efficient means yet found to ward off the attack of submarine torpedoes is a strong network of wire rope or chain, suspended from booms and completely encompassing the vessel. It is difficult, however, to construct a network which cannot be broken through by the larger sizes of fish torpedoes at short range. A plan of combining with a strong netting a system of countermines which destroy the attacking torpedo has been proposed by Mr. Park Benjamin, and has received the approval of high authority, but has not been practically tested.

The simple netting, or a system of floating booms surrounding a vessel, can be surmounted by torpedo launches having spars so arranged that they may be lifted over the obstruction and dipped down to strike the vessel below the water-line. Against boats which can be seen there is little doubt but that the Hotchkiss revolving cannon forms an efficient defense. For details of experiments with this weapon against torpedo launches see Ordnance—Machine Guns. The electric light is used on men-of-war to illuminate the horizon, and thus render the approach of torpedo boats visible. A cordon of guard-boats around the vessel, to intercept torpedo launches, has also been used. Various plans for thickening a vessel's bottom to enable her to withstand the explosion of a torpedo have been proposed; but these are radically erroneous, as any resistance which the vessel can offer will always be less than that of the water-tamping, and the explosion will vent itself wherever the least opposition is encountered.

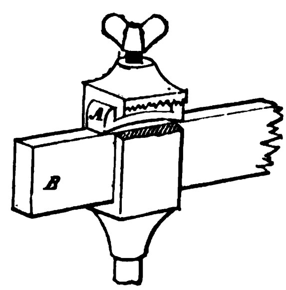
TRACTION ENGINE. See Engines, Steam, Portable and Semi-Portable.

TRAMMEL, or TRAMMEL-GAUGE. This tool, Fig. 4148, to which the term beam compass is also applied, consists of a bar *A*, of iron or wood, carrying two sliding pieces *B C*, having steel or pencil points. For draughtsmen's use it is made much lighter than is here shown, and is provided with set-screws instead of wedges, and between the end of the set-screw and the edge of the beam or bar is interposed a small spring shown at *A* in Fig. 4149. The office of the spring is to keep the bot-

4148.



4149.



tom of the slot in the trammel and the edge of the beam in contact when the set-screw is loosened, so that tightening the screw may not throw out the adjustment of the pencil-point. J. R.

TRAP, STEAM. See HEATING BY STEAM AND HOT WATER.

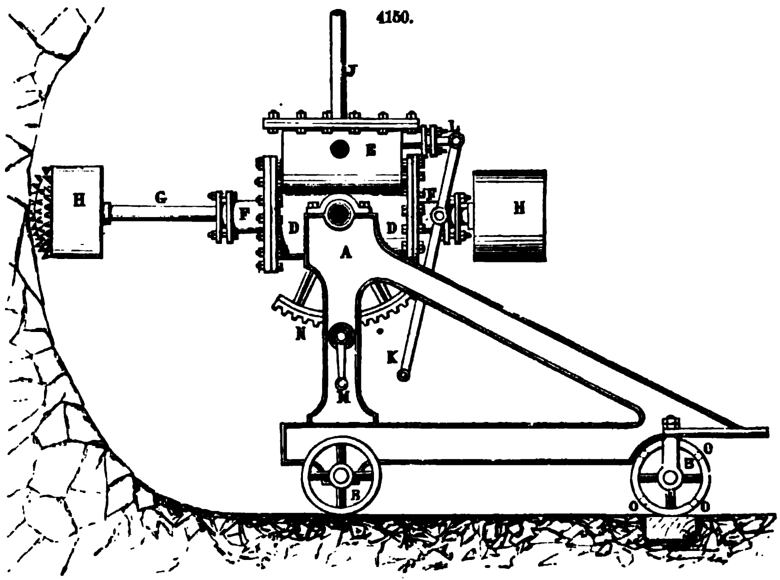
TRIP-HAMMER. See HAMMERS, POWER.

TRUSS. See BRIDGES.

TRUSSING MACHINE. See BARREL-MAKING MACHINERY.

TUNNELING MACHINES. *Battering-Ram Tunnel-Borer.*—Fig. 4150 represents Penrice's battering-ram tunnel-borer, which works on the principle of the steam-hammer. By suitable mounting of the cylinder on the trunnions of a gun-carriage, it can be made to take all the positions of a marine

4150.



or siege gun, and strike the rock with blows of 8 or 10 tons energy. The hammer weighs 2½ tons. *A* is the framing suspended on the wheels *B*. The end wheel serves to direct the carriage, and the whole is moved forward by the aid of a handspike inserted in the holes *O* in this wheel. *D* is the steam-cylinder, mounted on trunnions, and its angle is determined by the segment *N* and pinion and handle *M*. *E* is the valve-chest; *K*, the hand-lever by which the valve is actuated; *H'* is a heavy balance-weight; *H* is the ram-head fitted with cutters; *J* is the air-pipe for conducting the compressed air which drives the apparatus. By moving *K* backward and forward, the hammer *H* will be made to act as a battering-ram on the face of the heading in a way that will be obvious.

Beach's Tunneling Machine.—Fig. 4151 represents a tunneling machine devised by Mr. A. E. Beach of New York, and used in the partial construction of the proposed New York Underground Railway. The body of the shield is shown at *A*, and is simply a short tube of timber-work, backed by a heavy wrought-iron ring, against which the hydraulic rams *D* act to advance the entire machine. The front part of the shield is a heavy chilled iron ring *B*, brought to a cutting edge and crossed on the interior by shelves *C*, also sharpened. Bearing-blocks *E* of timber are placed against the masonry, as shown, on which the rams press when the shield is advanced. *F* is the pump from which the water is carried to the rams by the pipes *G*. *H* is a hood of thin sheet metal, within which the masonry is built in rings of 16 inches length, the bricks being interlocked. The pump is worked to cause the rams to press with a force of 126 tons against the end of the masonry. This forces the cutting edge and the shelves into the earth to a distance corresponding to the length of stroke

in the hydraulic cylinders, and, the earth being removed, the masonry is again advanced, and so on step by step. Whenever it is desired to alter the course of the shield, it is done by turning cocks in the pipes which lead from the pumps to the rams, on that side which is not to be advanced. The rams then acting upon the opposite side advance it.

4151.

Dowd's Tunneling Machine.—This machine is the invention of Mr. Olney B. Dowd of New York, and is designed for tunneling under the beds of water-courses where the material is soft and liable to cave in. It consists, as shown in Fig. 4152, of a cylindrical case *A*, with a head at the front end, through which projects a revolving shaft carrying a cutting or scraping arm which breaks or cuts down the earth. The shaft and arm are hollow, and suitable perforations are made in the latter, through which water is projected. This water mingles with the earth to form a thin mud, which may be removed from in front of the head by the pipe shown. With this pipe pumps are connected. In the bottom of the case *A*, and near the front end, is an oblique opening through which a large tube *W*, shown in dotted lines, may be pushed. By means of this tube a hole may be made in which to sink a bowlder or similar obstruction in the way of the case. The latter is forced ahead as fast as the earth is removed from before it, and it is followed by the wall of the tunnel built up in its rear.

In Fig. 4153 the tunnel is shown lined with sections of elliptical tube. The object of using sections of this shape is to enable them to be carried through the previously constructed portion of the tunnel, when no other means of access to the work exists. For this purpose they may be mounted on suitable carriages or trucks. These last consist of two independent plates, each having two wheels, and detachably clamped to the ends of the sections by a bolt, so that a section of the tube forms a portion of the truck itself when in working condition. The tube sections are grooved and tapered so as to match tightly, packed with lead, and screwed up by lugs and bolts, as shown in Fig. 4153.

4152

4153.

Work for Reference.—See "Tunneling, Explosive Compounds, and Rock-Drills," Drinker, New York, 1878.

TURBINE. See WATER-WHEELS.

TURNING. See the various articles under LATHE, etc.

TURN-TABLE. See RAILROAD.

TURRET-LATHE. See SCREW-MAKING MACHINERY.

TUYERE. See FURNACES, BLAST, and FURNACES, CUPOLA.

TYPE-SETTING AND -DISTRIBUTING MACHINERY. The problem of the application of machinery to composing and distributing type has engaged the attention of many inventors in Europe and America. Great improvements have been made in the manufacture of type itself, in electrotyping and stereotyping, and in printing machines. But the task of arranging types in line, ready for printing, is still almost universally performed as in the days of Gutenberg and Faust; the human fingers lifting from its receptacle each successive letter or space, and depositing it in place in the "stick" before going for another. And after each new arrangement of the type has fulfilled its purpose, and the matter has been stereotyped or electrotyped or printed from, the types have all these centuries been returned by the human fingers again, each singly, to its proper place, there to lie with its fellows in a promiscuous heap, waiting for the fingers of the compositor again to summon it to a place in a new combination. The day's work of the compositor still remains theoretically at 6,000 ems, composing, correcting, and distributing; such 6,000 ems of solid type involving the separate handling of about 28,800 separate pieces of metal. Practically, compositors out of newspaper offices

do not average the traditional 6,000 ems. More than 80 United States patents have been issued for improvements in type-setting and -distributing, and more than 90 in Great Britain, besides many on the continent of Europe and in Canada, whose general features are, however, almost all to be found in the American and British patents.

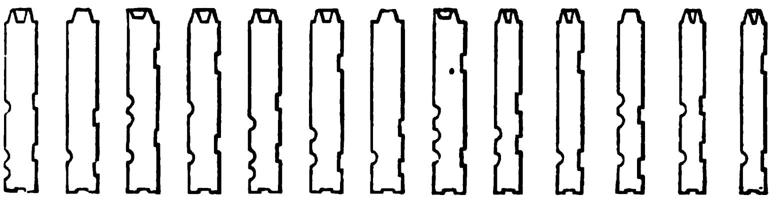
Sizes of Type.—American and British types are made of the uniform height of $\frac{92}{100}$ of an inch. Their depth, or dimension up and down the line, slightly varies in different foundries for the different sizes. George Bruce of New York, in 1822, arranged a standard bringing each size into exact proportion with the others, each size being made 12.2462 per cent. larger than the one next smaller, and doubling at every seventh size in any part of the series.

The thickness of type, or its dimension along the line, varies indefinitely, according to the style of letter. An alphabet, the small letters *a* to *z*, set up in line, will measure in the neighborhood of 12½ ems or squares. In a "fat" font the letters are thicker, and the alphabet measures more than 12½ ems; and in a "lean" font they are thinner, and measure less than 12½ ems. All blanks, however, spaces and quadrats, are made of a determinate thickness in all fonts of the same size.

The unit of measurement in the United States is 1,000 ems or squares. If 25 ems or squares of say bourgeois type will go in a certain "measure" or width of column, then the length of 40 lines down that column will make 1,000 ems, whether the matter is solid or leaded. The "blank" in the page, whether in leads separating the lines, quadrats at the beginning and end of lines, or open spaces in the page, are the printer's "fat," to be paid for as solid matter. An average solid 1,000 ems contains about 2,400 separate pieces. In Great Britain the unit of measurement is the 1,000 ens, or half the space occupied by 1,000 ems.

On the edge of the type, under the foot of the letters, are cast certain "nicks" or notches, one, two, or more to a type, in different positions. These serve to indicate to the compositor how the types are to be laid into his stick, and also to differentiate fonts of type. If there are several fonts or styles of say brevier in an office, the bodies of the same depth, if all were nicked alike, there

4151.



A, Small Pica No. 1. *B*, Small Pica No. 2. *C*, Small Pica No. 3. *D*, Small Pica No. 4. *E*, Long Primer No. 1. *F*, Long Primer No. 2. *G*, Long Primer No. 3. *H*, Long Primer No. 4. *I*, Bourgeois No. 1. *J*, Bourgeois No. 2. *K*, Bourgeois No. 3. *L*, Brevier No. 1. *M*, Brevier No. 2.

would be danger of the mixing of fonts. But the varying nicks enable the compositor easily to discriminate one from another. Fig. 4151 is a line of type with varying nicks. The rounded nicks are those made in the type-foundry, the square ones being cut in after casting for a use in the distributer hereafter to be described.

Type-setting.—In hand-work the compositor takes his place before his stand, on which lie the upper and lower cases—shallow trays divided into compartments, a compartment for each character. If his case is empty, he must first distribute. He takes up a handful of dampened type (called "matter"), resting it in his left hand, the nicked edges of the type uppermost. With the thumb and first fingers of his right hand he takes off a dozen letters more or less, and throws them one at a time each into its own compartment. This he does at the rate of 2,500 to 4,000 ems per hour. When his case is full enough and the type has become dry, he is ready to "compose." Taking in his left hand his stick and rule, and reading a portion of his copy, he fixes with his eye a particular character, picks it up with his right hand, and places it in his stick at its extreme left, with the nicks outward and upward, selects and places the next letter to the right of the first, and so on, keeping his left thumb on the end of the forming line. When he has composed enough for a complete line, he justifies, that is, adjusts the spaces between the words, adding or diminishing so that the line may be of full length. He must divide words as little as possible, and not on one letter; nor must he divide a single syllable: such words as enough, thought, through, etc., are not to be divided. When a line is justified, the compositor withdraws the rule from under and places it over the line, and composes a new line, until his stick will hold no more, when he grasps the whole mass with the thumbs and fingers of his two hands, presses all together, and "empties," that is, removes it bodily from the stick and places it on the galley.

Type-setting Machines.—The earliest patent for machinery to do the compositor's work is an English one, taken out by William Church—said to have been a Connecticut man—in 1822, and was organized, 1, to cast type and leave them in reservoirs; 2, to set them into line from these reservoirs by key motion; and 3, to print from them. Of course, the type being cast new for each use, no distributer was needed. The third English was the first American patent, that of James H. Young and Adrienne Delcambre, June 22, 1841. The first English distributer was that of Etienne Robert Gaubert, 1840, and the first American that of Frederick Rosenborg, Sept. 9, 1843, previously patented in England in 1840.

The Westcott Type-setting Machine differs from all other apparatus. It operates by the touching of a key to cast a new letter for each use and leave it in its proper place in the line.

In type-founding, types are cast in moulds containing at one end a copper matrix of the character. The aperture through which the melted metal is injected is at the end of the mould opposite the matrix, and a piece as long as the type, called the jet, extends through the aperture from the bottom of the type. Thus imperfections in the metal and variations of temperature spend themselves in the jet, leaving the body of the type comparatively perfect. The types thus cast go through various processes, such as breaking off the jet and ploughing in its place a shallow groove across the foot, thus leaving each type two "feet" to stand upon, "rubbing," etc.; and at last, set up in long rows, they pass under the eye of an expert, who, as he examines them carefully with a glass, rejects all in which he detects any imperfections. In these processes an average of 10 per cent. is eliminated; so that of 100 lbs. cast only 90 lbs. are actually fit for delivery.

General Construction of Type-setting Machinery.—With this exception of the Westcott machinery, all the American setters are made to take types from reservoirs by the touching of keys, and to bring them into place in the forming line. The ways of doing this are various, some bringing the letters from the reservoirs through converging raceways into the line, others driving all letters into a straight raceway along which a shuttle urges them to the line, and others using a circular raceway. Much time, thought, and money have been expended on these various attempts; especially upon the Alden series, the Felt machine, the Mitchel machine, the O. L. Brown machine, the Paige machine, and those invented by Houston, Dickinson, and Lorenz. Some machines distribute automatically, selecting letters by nicks or notches cut in them for that purpose, and some finger back by the human will, reversing the operation of setting.

In the *Alden Type-setting Machine* the letters are in separate channels ranged as radii about a slowly revolving horizontal wheel. Near the circumference of this wheel are a series of "conveyers," each one adapted to take or to leave a single type. These conveyers are slotted in the direction of their length, and are governed by a pin on the wheel extending through the slot, so that they can stop an instant as the pin moves with the constantly revolving wheel, and then "catch up" again by a spring. The letters are selected for setting by pins or tumblers set by the keys, and are distributed in a reverse manner. Each alternate conveyer takes and leaves a letter, so that setting and distributing go on at the same time. This method is expensive, complicated, and slow, and is supposed to be wholly given up.

The Mitchel Machine is one of the older forms. The pressure of a key liberated a type upon a tape, of which there was one for each letter, and on its tape each type reached its place in the forming line. Several types could be on the way at once, but would arrive in the order in which the keys had been touched. The letters were distributed by a revolving wheel which caught them by their machine-nicks and deposited them in lines. Kindred to the Mitchel setter is that of A. C. Richards, in which the types are fingered by keys upon an endless apron, on which two converging straps, traveling at a speed different from that of the apron, bring all letters to the line in the order in which they are touched.

The Delcambre and Kastenbein Type-setting Machines present points of strong resemblance. The Delcambre setter brings the types down upon converging inclined channels to the line. In the Kastenbein setter the types lie on their edges in closed separate reservoirs, from which they fall down vertical converging channels to the line. In both the Delcambre and the Kastenbein distributers the reservoir for each letter opens obliquely out of a central channel with a little valve which normally closes these side channels, keeping the central one intact. The key-pressure sends a single letter into the central channel, and at the same time swings the valve at the head of the appropriate reservoir so as to switch the letter into it. The Kastenbein machines have been used in the office of the *Christian Union* in New York, and in that of the *London Times*, in the Government printing office at Berlin, and elsewhere. Mr. Kastenbein has recently (1879) replaced his key-distributer by one in which the types are placed by hand, one by one, in the mouths of tubes leading directly to the type-reservoirs.

The O. L. Brown Type-setting Machine was arranged to deliver type into a curved channel held in the hand, from which it was pushed into a continuous line and afterward justified by the operator. The distributer was automatic, using nicked type and tumblers arranged around a cone.

The Felt Type-setting Machine was organized to perforate strips of paper by key-action in setting the type, and to distribute by means of these strips. Of course justification and correction made the perforated strips useless.

The Paige Type-setting Machine uses reservoirs in which the types lie edge to edge, from which the key-motion forces the lowest type into a race running along their lower ends. The keys are so arranged as to allow of combinations of type being touched into the race at once. At each beat a shuttle drives one or more letters—whatever may have been forced into the race at one depression of a key or keys—through the race and into the line.

More than one machine attempts to harness electricity to the work of setting or distributing types. Machines operated by air-blast have also been devised. Scores of patents have been obtained for machines which have proved impracticable.

The Dickinson-Lorenz Machines have been applied to actual work in New York with notably successful results. The apparatus is in two parts, and consists, first, of mechanism for composing the type in a continuous line, justifying from this continuous line into the required measure, and depositing in order upon the usual galley; and second, machinery for distributing "dead matter," that its types may be again used. Perspective views of these machines are given in Fig. 4155, the distributer being on the left, and the setter and justifier on the right.

The combined case is common to the composing and distributing machines, being filled in the latter and emptied, or set out, in the former. This case is a series of 28 parallel channels, in which the types stand in regular rows, side against side, and with faces outward and all pointing in the same direction. The width of each of these channels allows of the easy passage through it of type of

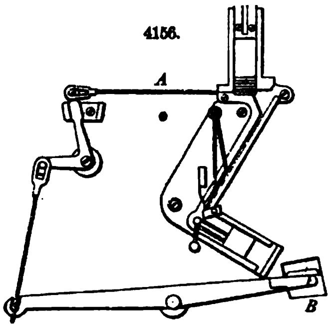
4188.

THE DICKINSON-LORENS TYPE-SETTING AND -DISTRIBUTING MACHINES.

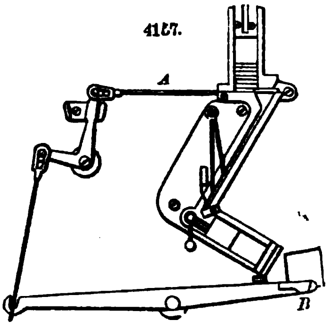
two neighboring sizes, as long primer and bourgeois, or bourgeois and brevier, without danger of disarrangement; and the depth of each is a trifle more than the height of type.

In the composing machine three of these cases, containing together (3 × 28 =) 84 channels, are arranged at the top of the machine, each in its separate "cradle." This cradle is a frame which can be rocked into a horizontal or into a perpendicular position, and contains ways upon which a case may be slid in or out, a glass plate against which the fronts of the cases rest when the cradle is in a perpendicular position, a rubber-covered roller against which the faces of the types may be arrested, and a rack cut corresponding to the width and thickness of each letter. The cradle is rocked to the horizontal position, and the filled case slipped into it and rocked to its perpendicular position, in which the faces of the types are all in view of the operator through the glass. Behind the bottom of each channel of the case is the steel pusher *A*, Figs. 4156 and 4157, which the depression of the corresponding key *B* will force through the slot at the bottom of the case against the foot of the lowest type in the channel, which it will force forward out of the case. The key being released, a spring withdraws the pusher, and the row of types, under their own weight and that of a free slug, falls to the bottom of the channel, leaving the next type in position to be forced out by the pusher when its key shall again be touched. Fig. 4156 shows the pusher *A* retracted, and Fig. 4157 the same forcing the lowermost type out, after the key is depressed.

4156.



4157.



As the type is driven out of the case by the pusher, its face end is projected upon a rest against the rubber-covered roll before referred to, and its foot, pushed off the bar of the case, drops into its own channel in the front-plate upon its glass, down which, foot foremost, it slides. The front-plate is a series of converging grooves, one to each letter, cut in a metal table. This grooved plate, with its covering glass, is set at an angle, inclining downward and backward, so that the glass covers all the grooves and becomes the bottom of each channel.

At the foot of the front-plate is a pendulum gate through which the types pass into a race or channel, in which the continuous line is formed. A cam running in the race, just under and behind the gate, drives each letter as it drops and the whole line beyond it ahead, keeping continually open a place to receive another type. Several types may be at the same time upon their way from the case to the race, but they will arrive at the race in the order in which the keys were touched. In the case and in the front-plate they are always in plain view of the operator.

The race, beginning at the gate in a line directly opposite the operator, is curved to his left, and conveys the forming line to the justifying mechanism. One side of the race, for a few inches before it reaches the justifier, is provided with a thin brush, which keeps the types upright under the pressure of a cam driving forward the line step by step. The justifier, holding in his left hand a "grab," adjusted to the required measure or length of the desired line, draws the needed length from the line into the composing stick, which is simply a composing rule with two abutments upon a bottom, where he justifies the line. Convenient to his hand is a series of channels of spaces, standing nearly upright; and at the bottom of each channel are two thumb-pieces so arranged that the pinching of them together leaves between the thumb and finger of the operator one, two, or three of the particular quadrats or spaces he may desire. As spaces are thus driven from the bottoms of their channels, a free slug resting upon the column instantly brings down the remainder of it to the bottom of the channel. The operator soon learns automatically to seize such spaces as he needs, and can concentrate his eyes uninterruptedly on the line he is justifying. Underneath his line is an inclined plane upon which the types rejected from the line in justifying drop, and are led again into a channel down which they are forced by a cam ready to be again placed in position for the justifier's fingers.

When the line is thus justified, and while the operator may be cutting off with the grab a new line, the pressure of the foot upon a treadle lifts the composing rule above the level of the face of the type, and pushes the line out of the composing stick and into the galley below, which is arranged to receive and hold the required measure. On the release of the treadle the composing rule sinks again to its place, and the stick is ready to receive the type which is to form the next line. If the matter is to be leaded, the leads are put in place by the same pressure of the treadle. The composing stick, rule, and width of galley-room are adjustable to the required measure, and the usual galleys are employed, being easily and quickly put on and taken off. The cam which pushes along the types in the forming line, and those which perform the same office for the spaces rejected in justifying, are revolved continuously by power.

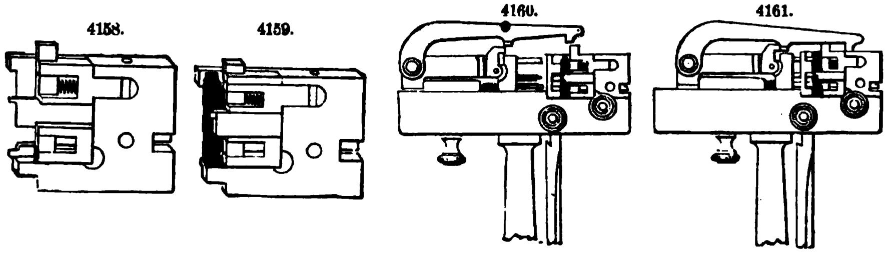
In the Lorenz-Dickinson distributer, a page or block of type is put upon the galley, and kept continually pressed toward the machine by a weighted follower. Under the forward line of the page an elevator-plate rises and falls. On this plate one line at a time of type is lifted into a channel, along which it is pressed toward and into the machine by another weighted follower traveling at right angles to the first. One character at a time is cut off from the end of this line by a spring-actuated type-driver vibrating at right angles to the line, which bears against a roller follow-

ing a cam on the main shaft, and so is made to select the first type only, whatever its thickness. When the last character of a line has passed into the machine, the plate automatically sinks just below the level of the bottom of the line, the page is forced forward over it, and the plate again rises with a new line; and so on, until the last line of the page enters the machine.

As each type is pushed off the line by the type-driver, it is received by one of a series of carriers, represented in Figs. 4158 and 4159. Fig. 4158 shows the carrier empty, and Fig. 4159 the carrier holding a type. As the type-driver pushes forward each new type, the plunger driving the characters in the front row by means of a stud on its face opens the spring above referred to, in exact time to receive the type; and as the plunger recedes, the withdrawal of the stud allows the spring to close upon and hold the type. The next beat of the machine moves forward to the right this loaded carrier, and brings into its place another carrier ready to receive the next type, and so on.

The edge of the type opposite the usual foundry-nick is notched or nicked with two shallow machine-nicks, with differing positions for every type used in the distributer; and this edge as the type stands in the carrier is exposed to the action of the nick-pin and feeler mechanism, carried on the

4158. 4159. 4160. 4161.



feeler-slides. Each of these feeler-slides, of which there are as many as there are kinds of type or "sorts" to be distributed, has a short reciprocating motion with each beat of the machine, to and from the front line of carriers. Each slide carries two pins adapted to enter the exposed nicks of its particular type, and a hook pivoted at the rear of the slide, and resting near its centre upon a rest-block actuated by a rod, the front end of which is in alignment with the nick-pins. This rest-block on which the hook rests is a lever pivoted at its bottom, and the pin engages with it near the pivot. Thus the top of the block, on which the hook rests, is pushed back a distance greater than the travel of the rod, which is only the distance which the nick-pins enter the type. As the carriers pass along step by step as before described, they rest for an instant in front of each feeler-slide, and while they rest the feeler-slide comes forward to the type. If the nick-pins and the nicks in the type do not correspond, the pins and rod carrying the rest-block remain in line, the spring against the bar moving the feeler-slides is slightly compressed, and the hook slides forward and back over the ejector top without touching it. But when a carrier presents to a feeler-slide a type whose nicks correspond to the nick-pins of that slide, the nick-pins enter the nicks and go forward a little. (In Fig. 4160 the feeler-slide and carrier-pin are shown. Here the pins and nicks do not match, and the hook remains up. Fig. 4161 is the same, but with the hook down, the pins and nicks corresponding.) This brings the rest-block rod against the exposed edge of the type at a place where it is not nicked; and the rest-block, remaining still while the slide goes forward, is pushed relatively back behind the hook-rest, and the hook drops beyond and below the ejector. As the slide recedes in its backward travel, the hook engages with and draws out the ejector, and by consequence the character resting against it. Before coming forward again a trip movement, actuating a bar running under the whole series of hooks, elevates upon its rest-block any hook that has been dropped, so that a hook can draw only one ejector, unless again dropped by a new entrance of the nick-pins into appropriate nicks.

Each type as it thus leaves the carrier is drawn into a channel in a front-plate, through which it can drop easily but cannot turn. Each of these front-plate channels leads into the top of a conductor-tube, which leads the type to its appropriate place in the case below. These conductor-tubes are square metal bars. In each a groove is cut spirally, so that the type received from the carrier through the conductor-tube reaches the bottom turned one-quarter around. When a case is put into the distributer, the slugs previously mentioned are pushed by hand to the head of the case, or against the type remaining in the channel. As each character drops, it is pushed forward and down the channel, the column and free slug resting against the spring-slug, which yields step by step as pushed. The head of each column in the case is always open for the reception of a new character, and each character as dropped is pushed out of the way and arranged in orderly column against the slug, gravity preventing any character from falling backward toward the head of the case. When any of the channels have become filled, the case is taken out, passed to the composing machine, and replaced by a case which needs replenishing.

Any type having no machine-nick, which enters the distributer, of course must pass by all the regular feeler-slides. Such types are arranged in orderly rows at the end of the machine, being drawn out according to their thickness. The last hook is arranged to drop at every beat of the machine, so that no carrier can enter the back row holding any type.

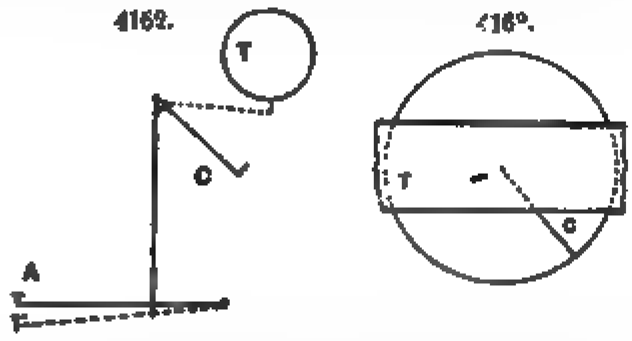
These machines are easily run at 4,000 to 6,000 ems per hour. One pair of operators have averaged about 4,000 ems an hour since May, 1878; and in a single week in the summer of 1879 one pair of operators set and justified more than 335,000 ems, partly solid and partly leaded with 6 to pica.

S. W. G.

TYPE-WRITER. A machine in which movable types are caused to yield impressions on paper to form letters and words, through mechanism operated from a keyboard. The object of the apparatus is to produce legible printed matter rapidly, and to substitute the same for ordinary writing.

One of the earliest forms of type-writer was invented by Mr. S. W. Francis, and will be found described in detail in "Appletons' Dictionary of Mechanics" (1851). It is noteworthy from the fact that it contains the essential features of all subsequent devices of this kind, the chief of which is the "arranging of a row of hammers in a circle, so that when put in motion they will all strike the same place, which is the centre of said circle." The paper is placed over a roller which is moved over the hammers longitudinally, and which rotates at the end of a line so as to leave a blank space between the line completed and that which follows. Francis's instrument has a much more complicated action than the type-writer of the present time, the simple arrangement of which is shown in the diagrams, Figs. 4162 and 4163, the latter being a plan. Here T is the roller on which the paper is received; C is the type-lever, which is pivoted near each end, and is brought up to strike the paper by pressing down the key A as indicated by the dotted lines in Fig. 4162. Between the type and the paper passes an inked ribbon, and this is directly struck by the type, the impression being left on the paper above.

4162. 4163.



The most improved modern type-writer is the so-called No. 2 machine manufactured by Messrs. Fairbanks & Co. of St. Johnsbury, Vt. This machine, represented in Fig. 4164, is so constructed that it prints either capital or small letters, at the will of the operator. The keyboard, having 40 keys or press-buttons, is shown in front of the machine. The apparatus is composed of two portions: the body, containing the keys, action, type-levers, and inking ribbon; and the carriage, in which is the rubber-covered roller over which the paper is placed. The carriage moves across the top of the body on rails. Motion is imparted to it through a strap which is connected to a cam or fusee-shaped spring-wheel, and the tension of which may be diminished or increased by means of a worm-wheel and crank. On the under side of a bar attached to the rear of the carriage is a rack. In the teeth of this rack engage dogs which are connected to a vibrating bar on the rear of the body. This bar communicates with all the key-levers, so that whenever a key is pressed down the bar is turned on its axis and the dog is removed from the rack. The carriage is then moved to the left by the action of the spring-wheel, but is prevented from traveling more than the space covered by one tooth of the rack by a second dog, which engages in the next notch. It will be seen, therefore, that whenever a letter is impressed on the paper the carriage is automatically moved onward, so that a blank space is left between the letter printed and the one following. As soon as the end of a line is reached a bell is sounded, and the operator removes the dogs from the rack, so that the carriage may be brought back quickly to its starting-point. In front of the body of the apparatus is a gauge-plate, and on the carriage is a pointer. By this means the operator is enabled to maintain lines of uniform width, or to adjust the paper so that the impressions may be made at any desired points.

4164.

An expert with one of these machines can imprint from 50 to 75 words per minute; and by the use of manifold paper, a large number of copies can be simultaneously produced.

VACUUM-PAN. See SUGAR MACHINERY.

VALVES AND COCKS. In all machinery put in motion by the action of a fluid or employed in pumping fluids, valves are required to regulate the admission and discharge. They therefore vary in form and construction, with reference to their purpose. Valves adapted to a large number of special uses are described in connection with the apparatus of which they form a part. For construction of valves used in steam-engines, see ENGINES, PROPORTIONS OF PARTS OF, ENGINES, STEAM, STATIONARY (RECIPROCATING), and other articles under ENGINES; also SLIDE-VALVE. Pump-valves are fully described in articles under PUMPS; valves used in the hydraulic press under PRESS, HYDRAULIC, and in the hydraulic ram under RAM, HYDRAULIC; in air-compressors, under AIR-COMPRESSORS; in brakes, under BRAKES; in flumes, etc., under MINING, HYDRAULIC, and AQUEDUCTS; in lock-gates, under CANALS. Safety-valves for steam-boilers are described under BOILERS, STEAM, and ALARMS; for balloons, under AIR-SHIP. For valves used on locomotive engines, see articles under LOCOMOTIVE; for those used in gas machinery, see articles under GAS; for those used in heating apparatus, see HEATING BY STEAM AND HOT WATER. Special forms of valves are described under ROCK-DRILLS, WATER-METERS, and WATER-WHEELS.

Valves generally considered, with reference to the manner in which their motion is obtained, may be divided into four classes: 1. Valves opened and closed by hand; 2. Valves opened and closed by independent mechanism; 3. Valves opened and closed by mechanism so connected with the machine

as to render the times of opening and closing synchronous with the motions of the machine; 4. Valves opened and closed by the action of the fluid. With regard to the motion relative to the seat, valves may be classified as follows: 1. Flap- or butterfly-valves, which rotate in opening; 2. Lift- or puppet-valves, which rise perpendicularly to the seat; 3. Sliding valves, which open by moving parallel to the seat.

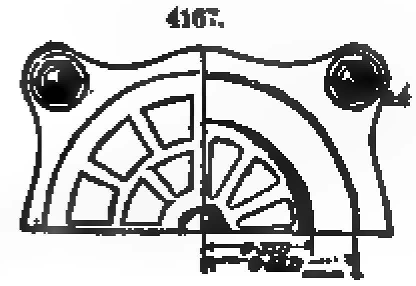
Flap- or Butterfly-Valves.—A simple form of flap-valve is represented in Fig. 4165. It consists of a leather disk strengthened and stiffened by two plates of metal, which at the same time give weight enough to the valve to close rapidly when the pressure beneath it ceases. A butterfly-valve consists of two flap-valves placed hinge to hinge, or sometimes edge to edge. In the latter position there is less interference with the movement of the fluid. The flap is sometimes entirely of brass, as in the case of air-pump foot-valves, where leather would not be sufficiently durable. Valves of this kind are most commonly lifted by the fluid.

Disk-Valve.—A form of valve extensively used for condensers and pumps consists of a circular disk of India-rubber, secured by a bolt at the centre, and resting on a brass grid which forms the

4165.

4166.

4167.



seating. The India-rubber, being flexible, lifts easily from the grating when any fluid pressure is applied beneath it, and closes again readily and without violent shock when the reflux begins. To prevent the India-rubber rising too high, a perforated guard-plate is placed over the valve. A valve of this kind is shown in Figs. 4166 and 4167. The valve-seat is attached to the cast-iron casing of the condenser by bolts, and the India-rubber and guard-plate are attached to it by a stud. The valve and guard-plate are removed from one half of the plan, in order to show the grating on which the valve rests. The India-rubber should not be too thin; three-fourths to seven-eighths of an inch thickness is sufficient; and the apertures of the grating should be so small that there is no great flexure of the India-rubber when resting on the grating. Moderate-sized valves of this description answer better than large ones. It is more satisfactory to use several valves of 7 in. to 9 in. diameter than to use a single large one.

The throttle-valve used on many engines, which consists of a circular or square metal disk, capable of turning about a shaft passing through it in the direction of a diameter, is a kind of double-flap valve. The disk is placed in a pipe, and closes the passageway when placed across the pipe, while it offers little resistance when parallel to the axis of the pipe. This valve is an imperfect equilibrium valve, the pressure on one half partly balancing the pressure on the other, so that the force required to move the valve is only equal to the difference of these two pressures. The equilibrium is exact, however, only while the valve is shut or so long as there is no sensible current passing it. If a rapid current is established, the pressure on that half of the valve which first deflects the current is greater than on the other half, thus tending to close the valve.

Lift- or Puppet-Valves.—These are very various in form, the simplest being a circular disk, usually of metal, with a flat or beveled edge, which fits a circular metal seating. These valves are generally placed with the axis of the valve vertical, so that their weight tends to keep them closed; but they may be otherwise placed if springs or rods are used to close them. In order that the valve may open an annular space equal in area to the circular passage under the valve, the lift must be equal to one-fourth of the valve's diameter. This lift is sometimes objectionable, because in closing the valve acquires a considerable velocity, and there is a shock at the moment of closing. This is not only prejudicial from the vibration it occasions, but it leads to the destruction of the faces of the valves and seat. Hence, with simple lift-valves, the lift is often restricted to a less amount than would otherwise be desirable, and then the resistance to the passage of the fluid is increased.

To find the area of opening of a valve in square inches due to a given lift, the following rules may be adopted:

(*a.*) When the lift of the valve is equal to or less than the depth of the seat: Find the product of (1) the diameter of the valve in inches, (2) the lift in inches, (3) the sine of the angle of bevel of the valve, and (4) 3.1416. Add this to the product of (1) the square of the lift in inches, (2) the square of the sine of the angle of bevel of the valve, (3) the cosine of the angle of bevel of the valve, and (4) 3.1416.

(*b.*) When the lift of the valve is greater than the depth of seat: Find the product of (1) the diameter of the valve in inches, (2) the depth of seat in inches, (3) the sine of the angle of bevel of the valve, and (4) 3.1416. Find the product of (1) the square of the depth of seat in inches, (2) the square of the sine of the angle of bevel of the valve, (3) the cosine of the angle of bevel of valve, and (4) 3.1416. Find the product of (1) the diameter of the valve in inches, (2) the difference between the lift and the depth of seat in inches, and (3) 3.1416. Add together these three products.

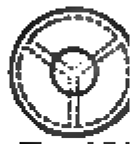
Example.—The diameter of a valve is 4 in., the bevel is 35°, and the depth of seat ¼ inch. What is the area of opening for a lift of ⅜ inch? $4 \times 0.25 \times 0.574$ (sine of 35°) $\times 3.1416 = 1.8$. Square of $0.25 \times$ square of $0.574 \times$ square of 0.819 (cosine of 35°) $\times 3.1416 = 1.85$. 4×0.125 (difference

between the lift and depth of seat) × 3.1416 = 1.57. 1.8 + 1.85 + 1.57 = 3.42 square inches, the area of opening required.

Fig. 4168 shows a conical disk-valve and casing. The valve is guided in rising and falling by three feathers, which fit the cylindrical part of the seating, and are shown in the plan of the valve. The lift of the valve is limited by a projection on the cover of the casing. The fitting part or face of the valve should be narrow, as it is then easier to make it tight. It must, however, present area

4170.

4168. 4169.



enough to resist deformation by the hammering action of the valve. The inclination of the face of the valve is usually 45° with the axis. Conical disk-valves may be actuated either by the fluid-pressure or by hand. In the latter case they are opened and closed by a screwed rod.

A ball-valve is represented in Fig. 4169. This acts in precisely the same way as a disk-valve, except that, as the surface of the ball is accurately spherical, it fits the seating in every position. The only guide required is therefore an open cage which limits the play of the valve. Such valves are often used for small fast-running pumps. The ball is often made hollow to lighten it.

The proportions of valves depend partly on the diameter. Thus the area of the waterway must be constant, and the linear dimensions of the casing are proportional to the valve's diameter. But the thicknesses are in most cases excessive as regards strength, especially in small valves, and do not increase in the same proportion as the diameter. For these the empirical proportional unit $t = \frac{1}{4}\sqrt{D}$ will be adopted, where D is the diameter of the valve.

Double-Beat or Cornish Valve.—The objection to a great lift in metal valves has already been mentioned. In the double-beat valve, two valve-faces are obtained in the same valve, and two annular spaces are opened when the valve lifts. For a given area of opening, the lift is only about one-half that of a simple lift-valve of the same diameter. Fig. 4170 shows a Cornish valve for a pumping engine. This valve is raised and lowered by a cam acting on an arrangement of levers. The lower seating is carried directly by the steam-chest. The upper seating is carried by four feathers or radiating plates cast with the lower seating. The valve itself is ring-shaped. Since the two valve-faces are nearly of the same diameter, another subsidiary advantage is gained in this form of valve. The valve is pressed down on its seat, partly by its weight, partly by the steam-pressure acting on one side of it. If the valve were a simple disk-valve, the steam-pressure would act on an area $\frac{\pi}{4} D^2$, where D is the diameter of the valve. As the valve is annular, however, the steam presses only on the area $\frac{\pi}{4}(D_1{}^2 - D_2{}^2)$, where D_1 and D_2 are the diameters of the two faces.

Sliding Valves.—Sliding valves are more commonly used than any others for stop-valves which are opened and closed by hand. They may be divided into two classes: 1, those with plane faces and seats; 2, those with cylindrical or slightly conical faces and seats. The former class includes engine slide-valves (see SLIDE-VALVE, and ENGINES, PROPORTIONS OF PARTS OF), and the sluices, often of very large size, which are used as stop-valves on water-mains. The latter class chiefly includes the hand-worked valves commonly known as cocks.

COCKS.—In ordinary cocks the seating is a hollow, slightly conical casing, and the valve, which is termed a plug, fits accurately in the seating. The passageway for the fluid is formed through the plug. By rotating the plug in one direction its apertures are made to coincide with the entrance and discharge orifices of the casing. The cock is then open. By rotating it in the other direction the holes in the plug are brought over blank parts of the casing, and the cock is closed. The slight taper given to the plug enables it to be accurately fitted by turning and grinding to its seating, and it can from time to time be refitted. Each time it is refitted the plug sinks a little lower in the casing. If the plug were cylindrical, this refitting would be impossible. The objection to the use of cocks in many cases, especially for pipes of large size, is that a good deal of power is required to move them, and this is partly due to the conical form, which increases the friction. The simplest cocks have a solid plug, which is kept in place by a screwed end. When the cock is small, the casing has a screwed socket on one side and a screwed end on the other, for the attachment of the cock to the pipes with which it is connected. But in larger cocks the inflow and outflow orifices are provided with flanges.

Proportions of Cocks.—For small brass cocks, with socket and spigot ends, the following proportions may be adopted: Diameter of waterway of cock, d; diameter of plug at centre, $1.15d + \frac{1}{8}$; height of hole in plug, $1.3d$; width of hole in plug, $0.6d$; total length of tapered part of plug, $2.5d$ to

$3d$; side of square for handle, $0.7d$; height of square for handle, $0.4d$; thickness of metal, $0.2d + \frac{1}{16}$; diameter of plug-screw, $0.35d$; diameter of screwed end, $d + \frac{3}{16}$; internal diameter of socket end, $d + \frac{3}{16}$; total length, $3.3d$; taper of plug, 1 in 12 to 1 in 9 on each side.

For cocks with flanged ends, like that shown in Fig. 4171, the proportions are the same. When the cock is not very small the thickness is best obtained from the rule: $t = \frac{1}{8}\sqrt{d} + \frac{3}{16}$ for cast iron; $t = \frac{1}{12}\sqrt{d} + \frac{3}{16}$ for brass. Some proportions are marked on the figure.

Large cocks connected with boilers, and in situations where failure would be dangerous, are best

4171.

4172.

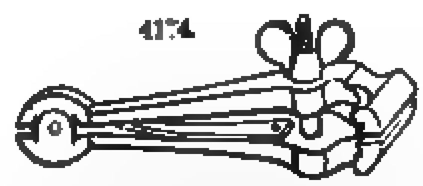
made with closed ends, as shown in Fig. 4172. The proportions of cocks of this description are a little different. Diameter of waterway, d; thickness of plug, brass, $0.12\sqrt{d} + \frac{1}{8}$; do., cast iron, $0.18\sqrt{d} + \frac{1}{4}$; thickness of shell, brass, $0.18\sqrt{d} + \frac{1}{8}$; do., cast iron, $0.25\sqrt{d} + \frac{1}{4}$.

The shell may be reduced to the same thickness as the plug in parts which do not require to be turned. Diameter of plug at centre, $1.18d$; size of openings in plug, $1.18d \times 0.66d$; overlap of plug at top and bottom, $0.08d + 0.4$; depth of stuffing-box, $\frac{1}{2}d + \frac{1}{4}$; depth of gland, $\frac{1}{10}d + \frac{3}{4}$; diameter of studs in cover, $\frac{1}{8}d + \frac{1}{8}$; taper of plug, 1 in 12 on each side. Some other proportions are marked in the figure.

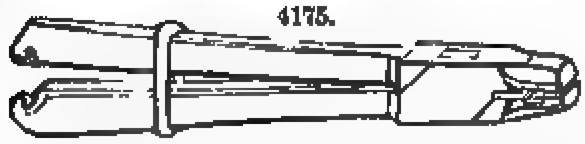
VISE. The essential requirements of a vise for holding metal-work are: Strength to allow of chipping or filing the work without the possibility of the vise breaking; the inertia of the anvil should be sufficient to absorb effect of blows; the jaws should move parallel and freely, and should be arranged so as to get the whole power of the screw.

4173.

4174.



4175.



4176.

Hand-Vises are used for holding small work, serving as a species of handle. Various forms of this implement are represented in Figs. 4173 to 4176. The tools shown in Figs. 4175 and 4176 are more properly pin or sliding tongs, and are closed by a ferrule that is drawn down the stem. Fig. 4176 shows a variety of tongs which has no joint, but is provided with springs which open when the ring *r* is drawn back. Fig. 4173 is known as a dog vise or pig-nose vise. The manner of using these vises is explained under FILING.

4177.

4178.

SCREW PARALLEL VISES.—*Prentiss's Vise*, manufactured by the Hall Manufacturing Company of New York, is represented in Figs. 4177 and 4178, the latter being a sectional view from which the

construction will be clearly understood. The back jaw is adjustable, and in use instantaneously conforms by automatic action to any angle, adjusts itself, and makes firm the object held, whether it be straight, beveled, or wedge-shaped. Or, if desired, by inserting the pin *A*, Fig. 4177, the jaw becomes fixed and immovable, thus making a parallel or solid-jaw vise. The adjustable jaw, resting and working as it does upon and against the solid body of the vise, is thereby rendered as strong and durable as the old permanent jaw. By means of the swivel bottom this vise may be readily adjusted to any angle, right or left, by raising the ratchet-pin *B*, which on being freed is forced home by a spring, rendering the vise firm as if stationary. The mechanism of the swivel bottom is such as to render it fully as strong as the stationary bottom, capable of carrying the heaviest class of work, and resisting successfully the shock of chipping.

4179.

The Miller's Falls Vise, manufactured by the Miller's Falls Company of Miller's Falls, Mass., is represented in Fig. 4179. It is a combination of the older Union and Backus vises, having a covered screw and a peculiar construction of the slides. The screw-covering is telescopic.

The Howard Vise, made by the Howard Iron Works of Buffalo, N. Y., is represented in Fig. 4180. This vise also has a covered screw, but differs in the construction of its slide from that previously described. A sectional view through the fixed jaw of the swivel-vise is shown in Fig. 4181. The spindle *B* passes through the table, and is secured beneath by the nut, turned by the handle *W*.

4181.

4180.

Parallel-Leg Vise.—The old fashioned leg vise consists of a fixed vertical leg, usually attached to the side of the bench, and a movable leg, pivoted between arms or plates secured some distance down on the fixed leg. The jaws of the vise are held apart by a spring, and brought together by a screw which is passed through or into a pivoted nut in the fixed leg. The jaws of this vise are, however, not parallel; and to remedy this difficulty vises of the type represented in Fig. 4182 have been devised. The engraving shows an improved vise constructed by Messrs. Fisher & Norris of Trenton, N. J. It is made to act parallel by causing the front end of the lower jaw to have the same movement in and out with the upper part, instead of opening on a hinge, thus always bringing a square pull on the thread of the back jaw, which therefore can be made solid and immovable as the vise itself. The "grip" is obtained by the one powerful upper main screw with a lever of liberal length, and the parallel movement is secured by the use of another screw at the lower end, and of the same pitch as the upper screw, and moved by it exactly the same distance in and out. This lower screw is easily moved, as when screwing up against a piece between the jaws the tendency of the lower end of the jaw is to go in of itself, the chain only regulating its movement. And in opening the vise there is no strain on either of the screws; therefore it is claimed that the chain used to preserve uniform movement suffers no wear and is as durable as any other part.

4182.

Pipe-Vises are of two kinds: those especially designed for their purpose, and pipe-holding attachments which may be applied to ordinary vises. Figs. 4183 and 4184 represent a vise of the first class, manufactured by D. Saunders' Sons of Yonkers, N. Y. In Fig. 4183 the vise is shown hinged so that it may be set at any angle, and in Fig. 4184 it is secured in a fixed frame. The jaws are made V-shaped, and are serrated so as to obtain a firm grasp of the pipe. The movable jaw is operated by the screw as shown

LEVER VISES.—The peculiarity of these vises is the absence of a screw, and the substitution of a lever combined with interior mechanism by which the grip is produced.

4183.

4184.

The Stephens Parallel Vise, manufactured by the Stephens Patent Vise Company of New York, is represented in detail in Fig. 4185. In the engraving the top of the vise is removed to show the working parts. These consist of a toggle G and tooth-bar t, held together by a spring S. The hook M and cam C, on the handle H, work the toggle-joint. A steel rack T is inserted in the sliding bar $B\,B$. The sliding bar is here seen disengaged, free to be slid either in or out. At the first move of the handle outward the hook M slips from the tooth m, and the spring S draws down upon a hook at U, firmly setting the tooth-bar t against the rack T; as the handle is pulled farther outward, the cam is brought to bear against the ridge n, nearly straightening the toggle, and forcing the movable jaw with great power against the object held. The vise in Fig. 4185 is shown with a swivel attachment. The lower part of the vise has a conical ring, which turns upon a corresponding conical ridge on the bed-plate R. A slight movement of the handle, which turns upon a bolt or stud fastened to the stock, serves to bind these conical surfaces tightly together.

4185

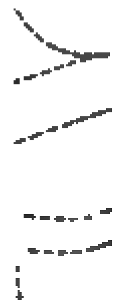
Hall's Sudden-Grip Vise, made by the Charles Parker Company of Meriden, Conn., is represented in section in Fig. 4186. The movable jaw A passes through the fixed jaw B. P is the bed-plate, above which is a steel rack-plate H. Attached to each side of the rear end of the lever-handle is a disk. These disks are inserted in the outer end of jaw A, and are held in place by friction-straps T adjusted by the screws S. On the inner portion of the disk is a pin K, which when the lever is raised as shown presses down the end of the pivoted bar J. Said bar raises the toothed clutch G, disengaging the same from the rack H. The jaw A may then be moved out or in to adjust it in contact with the work. When this is done, the lever-handle is pushed down. The effect is to release the lever J so as to allow the clutch G to drop, and also to draw a bar D, which is pivoted to the handle-disks, outward; and thus the end of the bar acts as a wedge to push down the toggle-joint E, and so to force the clutch G forward to act against the rack-teeth. As soon as the lever is raised to loosen the work, the coiled spring L, acting on the upward-turned end of the clutch G, carries the latter to the rear, and so removes it from the rack-teeth, and at the same time returns the toggle-joint to its normal position.

4186.

VISE ATTACHMENTS are contrivances applied to parallel vises to adapt them to special varieties of work. Fig. 4187 represents the taper attachment for irregular objects used with the Stephens vise. To one jaw is secured the piece shown on the left, which has a semicircular movable face-plate, which turns on its curved side and thus adapts itself to the shape of any object inserted.

4187.

4188.



Pipe-holding attachments are made in a variety of forms. Fig. 4188 is the attachment adapted to the Prentiss vise. The pipe-holding device is secured to the curved plates, which may be adjusted at any desired angle.

WAGON-BUILDING. The chief component parts of wagons and carriages are: 1, the body; 2, the wheels; 3, the gearing; and 4, the top or covering.

I. Bodies.—*Timber.*—For the framework of both wagon- and carriage-bodies, the ash (*Fraxinus*) possesses every requirement, being of a light but stiff texture, easily seasoned without springing, retaining the shape given to it by the mechanic, and, though coming under the head of hard woods, it is so easily worked that infinite varieties of shapes may be given it without great waste of time; moreover, it has an open grain, which gives a desirable foundation for gluing. A soft quality of ash is preferable in the case of a paneled-up carriage, where a good surface for gluing is the chief requirement; but in the case of a curtain-quarter carriage of any kind, the pillars should be made of a stiffer quality, to render the body less liable to spring, and to lessen the vibration, which is apt to fracture the joints at the arm-rails in this class of work. In the case of the rockers or chief framing pieces, which constitute, as it were, the backbone of the vehicle, and also for corner-posts and seat-frames, the stiffest and best straight-grained ash should be employed.

A difference of opinion exists as to the best material for the panels of carriage-bodies, the requirements being lightness, freedom from disposition to crack, smoothness of surface, and size sufficient for the widest panel without jointing. The timber seemingly filling these requirements most nearly is the white poplar (*Populus alba*), commonly known as "whitewood," which, though of rapid growth, is fine in texture, and retains its shape when steamed and bent. It is properly classed among the soft woods, and when well seasoned is durable. Whitewood is used almost exclusively for the body-panels of American-built carriages, an exception being made in the case of panels having considerable swell, as doors, where ash is preferable. English builders, on the other hand, prefer mahogany, but in the case of a landau, coach, or brougham, they generally cover the quarters with uncurried leather, to form a better foundation and surface for the painting. For seat-panels, whitewood, cherry, and sycamore are used, the last two being preferred, as their fibre is stronger than that of whitewood, rendering them less liable to split when screwing on the seat-irons, and under the strains to which they are subject.

II. Wheels.—*Hub Timber.*—There are several kinds of timber used for hubs. The woods chiefly employed are either sour-gum (*Nyssa multiflora*) or the white rock-elm (*Ulmus Americana*), both of which are well adapted for this purpose. The best elm is found on rocky and rough soil in all the Northern and Western States, and should be carefully selected. A stick 5 ft. long is about all that can be worked from each tree. Great care must be taken in seasoning, to prevent checking and splitting, which will occur if the bark is removed from the ends of the stick. Some, to prevent this danger, steam the blocks. One cause of the popularity of elm hubs is, that the spokes may be driven tighter sidewise than can be done with any other wood used. Sour-gum must not be confounded with the sweet-gum or pepperidge of the North and West, as it is of an entirely different nature. It requires a long time to season thoroughly, and a great amount of care to prepare it for the seasoning. The outer bark must be removed, leaving the liber or inner bark on to prevent checking; and a free circulation of air must be allowed to keep the sheds ventilated where it is piled, or "doting" soon sets in; but when perfectly dried, it will last for years without losing its qualities. It is of very

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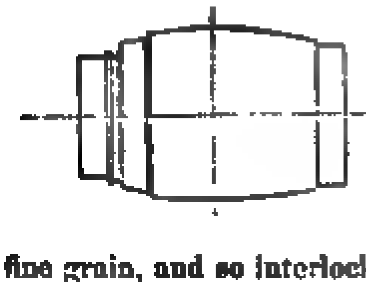
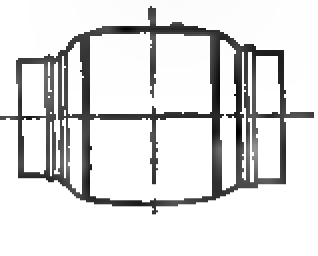


4190.



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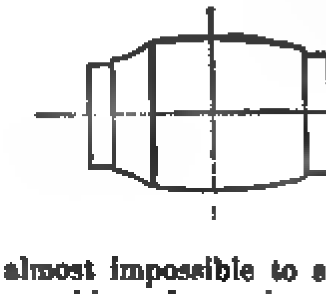

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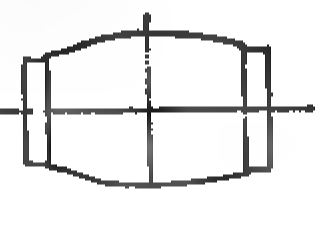
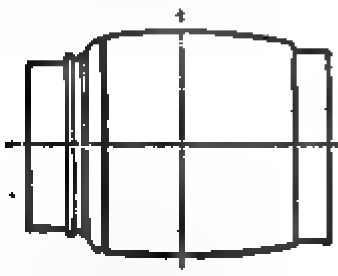


fine grain, and so interlocked in growth that it is almost impossible to split it. Failing to secure these woods, hard white birch, locust, black walnut, or white oak may be used for hubs.

Proportions of Hubs.—We have selected a few patterns of hubs now used. Fig. 4189 shows a very

popular style, size 4½ × 7 in. It is a good, strong pattern, and has at least three-fourths inch wood from face of forward spoke to beginning of first bead; not less than this amount should be given in making any design for beading. Fig. 4190 shows a hub of the same dimensions, with back band reduced to allow for fancy work, making a weak foundation. The amount of end grain exposed, together with the leverage of the spokes, renders this hub very liable to shell and crack. The hub shown in Fig. 4191 has, in the smaller sizes, all the elements of strength necessary; size 4 × 6⅞ in. Fig. 4192 shows the plain hub, much used for light sizes. It is not a strong pattern, on account of the slope of the curve carried to the front spoke; in small sizes this objection decreases. Figs. 4193 and 4194 show the American and English patterns in contrast, Fig. 4193 being the regular 6 × 8 inch American hub, the other the same size from the factory of a London coach-builder. The hub marked Fig 4194 would not last in this climate, with so much end exposure and so little solid support in front of the spokes. Fig. 4195 shows a full hub, and Fig. 4196 a sectional view of it cut longitudinally through the centre.

4193.



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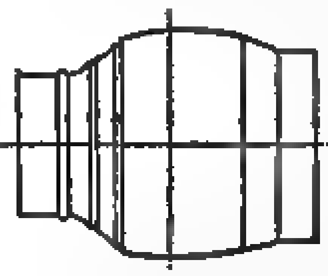

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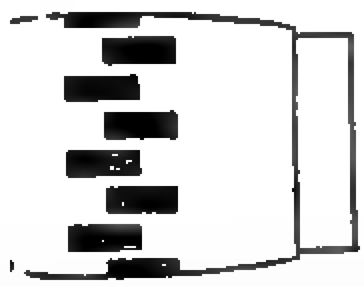


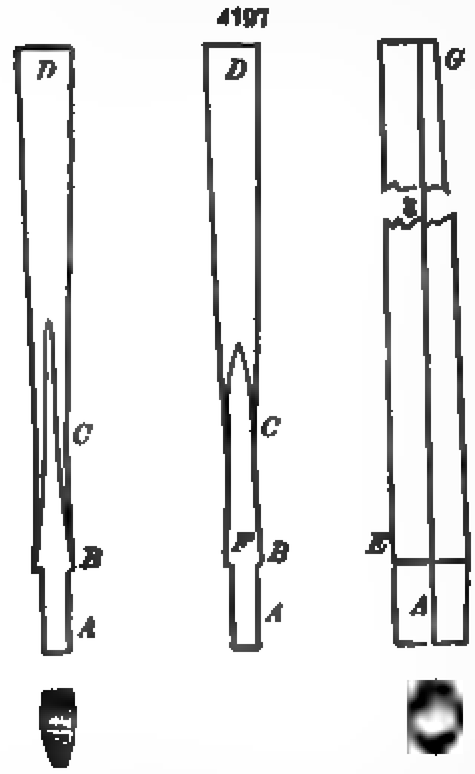
4196.

Spokes.—For spokes, either hickory or oak may be employed, the former being especially adapted for light wheels and the latter for the heavy grades. As the size of a wheel is written by giving the size of the spoke, we will give as an example a spoke that measures one inch across the shoulders (see Fig. 4197). For ease in reference we have divided this spoke into the following parts: *A*, tenon; *B*, shoulder; *C*, throat; *D*, body; *E*, face; *F*, back; *G*, end. This drawing is made to scale, and the written measurements are consequently not necessary. A spoke of these relative dimensions will stand, without deflecting, an average of 750 lbs. direct end-pressure, and about 200 lbs. in the direction of end-thrust or lateral strain.

Rims.—The rims of wheels are also made from either hickory or oak, and are bent to shape by machines specially designed for that purpose, those most in use being known as the Reynolds and Blanchard machines, illustrations and descriptions of which may be found in *The Hub*, xx., 888.

Patented Wheels.—Large numbers of patented wheels are in use, which demand brief mention. These may be divided into two general classes: 1. Those having the flanges of iron cast separately, and forced upon the hub after the spokes (which have short tenons) have been driven; the spokes form a solid arch around the hub, to accomplish which requires that each wheel should have two more spokes than the plain wheel. 2. Those which are made with a band of iron around the hub, through which are "cored" the mortises; this band is forced upon the hub before the latter is mortised, the spokes being driven through the mortises in the band into the wood of the hub.

4197



III. **Gearings.**—The principal parts of the gearing of a vehicle are the axles, springs, fifth-wheel, and shafts.

Axles.—Numerous patterns of axles are in use, more or less simple in construction, and adapted for different varieties of work. To understand the distinctions between the classes, a few definitions are necessary. The "arm" or "spindle" is that portion of the end of an axle which slips into the hub-box, and on which the wheel revolves. The "box" is a cylindrical metal tube fitted into the centre of the wheel-hub, forming the sheath within which the axle-arm revolves. The "skein" is a strip of iron imbedded into the upper or lower surface of a wooden axle-arm, serving as a protection against wear from the hub-box. The "collar" is a projection on the end of the axle-bed, forming the bearing against which the hub-box wears. The "nut-axle" is one in which the box is secured to the axle-arm by a nut instead of a linch-pin. The "thimble-skein axle" is a variety of the single-nut axle, the arm of which is cast hollow, to admit a wooden axle-tree. The "mail axle" is one in which the box is secured to the hub by three bolts, running through the hub and into a flange at the back of the collar; so named from its frequent use on the old English mail vehicles. The "half-patent axle" is a variation from the old "patent-screw axle," having a single nut on the end, and the box covering the collar. The so-called "Collinge axle" (named after the English inventor) is the most complicated and complete of the axles, and is specially adapted for the heavier grades of pleasure carriages. Its features are:

a large collar, against and within which the box revolves; generally a parallel arm; a slide, against which the recess in front of the box runs; the application of both right- and left-hand nuts, giving additional security; and the use of a linch-pin in connection with the nuts. A "cranked axle" is one whose bed is depressed or bent down, in order to allow the body to be hung low.

4198.

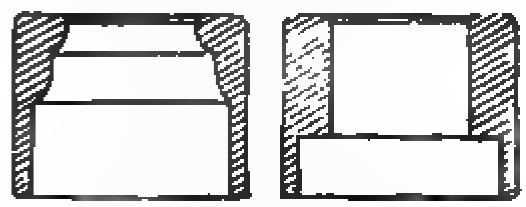
Axles are seldom forged in the carriage- or wagon-shop, but are supplied by manufacturers making them a specialty.

Rubber cushions are used in hubs with considerable advantage in lessening the shocks and vibrations to which vehicles are subjected. Fig. 4198 represents a section of a hub provided with such cushions. This device is termed the rubber-cushioned axle, and is manufactured by the Rubber-Cushioned Axle Company of New York. The cushions surround the axle-box and are imbedded in the hub. Their forms for two classes of axles are shown in section in Figs. 4199 and 4200. They are claimed greatly to reduce wear and tear, and to render the vehicle easier to draw.

Springs.—The varieties of springs most in use are known as the side-bar (mainly for buggies), elliptic, half-elliptic, and C springs, names that are self-descriptive of their form; the double-suspension, being a combination of elliptic and C springs; and the platform-spring, illustrated by Fig. 4201, of which a writer in *The Hub* gives the following description: "When we reach the heavier grades of platform vehicles, we are compelled to use three-quarter elliptic side-springs, combined with transverse or cross springs, as shown in Fig. 4202, in which *a* shows the upper section, *b* the lower section, *c* the head, *d* the shackle, and *e* section of cross-spring. This will be found the best combination for the back gearing of all vehicles having the front axle shorter than the back, its advantages over plain elliptics being its greater elasticity and strength, the concussions being more widely distributed, and the body consequently remaining more nearly in its normal position. By applying platform-springs, we gain a further advantage, in securing three bearings for the body upon the gearing, instead of two as with elliptics, and allowing a reduction in the number of plates and in the weight of the steel. The latter statement will be best illustrated by giving a few figures. With elliptic springs 38 or 39 in. long, it would be necessary to use, for a landau, five heavy plates of 1¼-inch steel; while with platform-springs we could use steel 1¼ inch wide, increasing the length at the same time to 43 in., using four plates ranging from No 3 to No. 4 steel, while the cross-spring would be made with three plates of heavy or four plates of light steel."

4199

4200.



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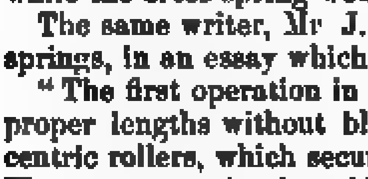

The same writer, Mr J. L. H. Mosier, gives the following suggestions upon the manufacture of springs, in an essay which was awarded a first prize by the Carriage Builders' National Association:

"The first operation in making springs is to cut the steel by power-shears, which clip it into the proper lengths without blow or shock. The points of the leaves are drawn by passing through eccentric rollers, which secures uniformity in the taper, and does not injure the structure of the steel. The next operation is welding on the heads. These are forged, rights and lefts, and welded to the head-plate in their proper position, by means of two horizontal hammers welding the sides, and a vertical hammer welding the flat surface of the steel, and at the same time shaping the head to fit the 'filler.' This is a marked improvement over the old way of welding a clip-lug on each side of the plate, turning a head in the vise, and forming it by means of a falling hammer and bottom swedge.

"Figs. 4202 to 4205 show various parts of the spring. Fig. 4202 represents the 'French head': *a*, the head; *b*, section of the plate; *c*, the end of the head on the plate. By the use of this head much of the elasticity of the main plate is sacrificed, and fracture is liable at the point marked *c*, or near that point. Fig. 4203 shows the so-called 'button-head,' as used on full elliptics: *a*, the head; *b*, section of plate. This head does not limit the action of the plate nor weaken it (as does the 'French head'), unless it is burdened with an excessive weight, in which case fracture is liable at or near the point where the head and plate are united. For all ordinary purposes this class of heads will be found well suited. The only substitute that we can recommend in place of the last described is the 'Berlin or German head,' Fig. 4204: *a*, the head; *c*, section of plate; *b*, point of connection between the two. By the use of this head the centre of the plate is brought on a line with the centre of the bolt-hole. Fig. 4205 represents a section of the lower half of the spring with the same 'Berlin head': *a*, head of filler; *b*, section of the plate. As in case of the upper section, the centre of the

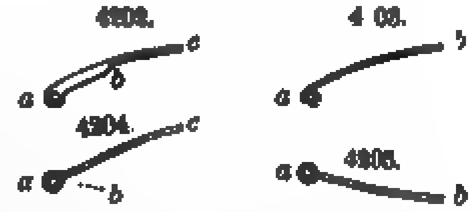

plate is nearly in line with the centre of the bolt-hole. Fig. 4206 shows a half section of this spring, with the upper and lower plates joined: *a*, the head; *b*, upper plate; *c*, lower plate; *d*, the beginning of the ellipse, which in this spring is truer than in any other, allowing the plates to touch only at the point *d*.

4206.

"To make the filler or head of the bottom plate, the best method is to make a solid eye, and drill the hole for the bolt. The bolt should fit as closely as an axle-arm fits its box. In fitting the filler in the head, care should be taken to allow a clear space between the filler and the upper surface of the plate, to prevent the grinding of the head on the filler. The sharp corners on the upper side of the filler should be removed, to prevent the filler from severing the inner portion of the head where welded to the plate, thereby avoiding the liability of loose or broken ears, which not infrequently occur when the fitting is imperfect.

"An elastic hickory bow forms a good model for the taper which should be given to spring-plates. In Fig. 4207, *a* indicates the end, and *b* the centre. Here we find a gradual taper from centre to point. The spacing and taper of the points should be as nearly equal as possible, after placing the first plate upon the main plate, and so drawn as to produce a true taper throughout. The effect of irregular tapering is shown in Fig. 4208, in which *a* shows the head, and *b* the centre. We find, with such a spring as this, that when weight is applied the spring is liable to assume the shape shown in Fig. 4209.

4207.

4208.

4209.

"With a view to increase the elasticity of springs, spring-steel is made of such a shape as to reduce the friction of the bearing surfaces to a minimum, by making the steel slightly concaved; this concave shape gives a bearing on the edges of the plates. It is almost impossible to fit two spring-plates together so that daylight may not be seen between the plates, but they should be fitted as closely as possible. To accomplish this, 'file-fitting' was introduced; but this process has some objections, increasing the bearing surfaces and consequently the friction, and also adding materially to the expense. Others grind the surface of the plates, on the principle that smoothness of surface must allow easier action and consequently greater elasticity. If, however, we simply remove the scales produced by frequent heating, and coat the bearing surfaces with graphite, the same end is attained with better results.

"The process of 'water-tempering' springs is not reliable, and the action of water upon heated metals is more or less harmful, where elasticity is aimed at. Water is productive of oxides, which are injurious to all metals. Oil, on the other hand, while it may not cool the outer surface as quickly as water, is more penetrating in its effects, and thereby renders the metal more homogeneous throughout. Linseed oil possesses all the requisite qualities for tempering spring-plates. The fire or furnace for heating the plates should be so constructed as to prevent a direct blast upon the plates; for if the heat be generated by the ordinary method, the metal is liable to be oxidized to a point where scoria would set in, which could not be corrected.

"Of the various grades of steel employed for springs, I prefer that known as 'Greaves's Swedes steel.' While cast steel may answer for all ordinary purposes, where elasticity is not required to the greatest possible extent, it should not be used for springs, on account of the shortness of its fibre and consequent lack of elastic strength.

"The best method of securing a correct action of springs is the proper graduating of the plates. A spring with its plates properly graduated, from its main plate to its shortest one, if otherwise well constructed, is better fitted to sustain weight and to impart elasticity than one of even calibre throughout."

The side-bar spring, peculiar to buggies, will be spoken of more particularly in connection with the working drawings of a buggy presented farther on.

The class-names of vehicles are frequently preceded by an adjective descriptive of their spring suspension, giving rise to a large number of convenient terms, such as "side-bar buggy," "double-suspension landau," "C-spring coach," "platform wagon," etc., which are self-explanatory.

4210.

Fifth-Wheels.—The fifth-wheel or circle of a carriage consists of two horizontal metal circles or sections of a circle (or one of metal and one of wood), placed between the upper and lower sections of the front gearing, and generally connected with these parts by a king-bolt; these plates, revolving one upon the other, allow the axle to turn laterally, and thus change the line of motion. Some fifth-wheels consist of two full circles, but there are also "half-circle," "three-quarter," "D," and "elliptical" fifth-wheels. Fig. 4210 illustrates a buggy fifth-wheel made of eleven-sixteenth-inch Norway iron, and having a diameter of 12 inches.

IV. Construction of a Square-box Buggy.—Having now defined all the principal constituents of wheeled vehicles, we select for careful analysis the square-box buggy, or road-wagon, the typical American vehicle, of which Fig. 4211 presents a side view; Fig. 4212, a half view of the front; Fig. 4213, a half view of the back; Fig. 4214, a half view of the ground-plan, looking down upon the vehicle; and Fig. 4215, a half view of the ground-plan, looking up from the bottom. We give below a full description of the manner in which a buggy of this kind is commonly constructed, the dimensions being furnished by J. L. H. Mosier, foreman smith with Brewster & Co. of Broome st., New York:

Woodwork of Body.—For the rockers and framework of the body, use ash. For some portions of bodies, as the drop-front, it is necessary to increase the sustaining power of the rockers by plating them on the inner sides with iron plates, known as "rocker-plates," secured to the rockers by wood-screws. The dimensions of the framework may be varied somewhat, according to the size, weight, and capacity of the wagon; the capacity of the wagon before us being two persons, together weighing

.25 lbs. The rockers may be made $1\frac{1}{4}$ to $1\frac{3}{8}$ in. wide and $1\frac{1}{2}$ to $1\frac{5}{8}$ in. deep, and the back end-bar of the same dimensions; but increase the width of the front end-bar by a quarter of an inch, to afford support for securing the feet of the dasher, and also for the foot-rail, or iron rod protecting the front

4212. 4211. 4213.

panel from the feet. The corner-posts are halved into the rockers, being of the same width as the latter, and three-quarters of an inch thick. The front corner-posts are left flat, to afford a surface on which to secure the dasher; while the back corner-posts are concaved to conform to the thickness of the panels. The seat-posts, or "uprights," are framed into the rockers, and left flat on the outside and concaved on the inner surface. For the seat-frame use ash, and for the panels of the seat whitewood, cherry, or sycamore. The dimensions of the body are dependent upon several conditions, including comfort, symmetry, and the desired weight and carrying capacity. The length of the box may vary from 4 ft. to 4 ft. 4 in., and the width from 17 in. (the narrowest consistent with comfort for two persons) to 32 in. The depth of the side panels may vary from 4 to 10 in. The distance from the bottom boards to the top of the seat-frame is commonly fixed at 12 in.; and that from the front of the seat-frame to the front panel at 24 in., which is necessary to afford sufficient foot- and leg-room.

For the body panels use whitewood, three-eighths inch at base, and one-quarter or five-sixteenths inch at top, secured at the corners by angle-irons resting on the upper surface. Halve or mitre the panels at the corners, and then glue them to the rockers, corner-posts, and seat-posts. Secure them additionally to the rockers by wood-screws, No. 10 standard, the panels being countersunk to permit of covering the screw-heads with wooden plugs or otherwise. The seat-riser is next added, or this may be made in one piece with the side panel, as is preferable.

The best builders do not make the box-body perfectly rectangular, as the following variations have been found to give a more attractive appearance: The width at the top should exceed that at the bottom from one-half to two-thirds of an inch, and the length at the top should be three-quarters of an inch or more greater than at the bottom.

The rockers are rabbeted out on the under inside surface, to receive the ends of the bottom boards of whitewood or pine, the latter being usually seven-sixteenths of an inch thick; these are fastened to the rockers by clout-nails or screws, and for further security a strip of ash, $1\frac{1}{4} \times \frac{3}{8}$ in., is attached beneath them.

In planning the seat-frame, allow 15 in. seat-room for each person in the finished vehicle. The usual height of the seat-sides is 5 or $5\frac{1}{2}$ in. at the front, increasing one-half to three-quarters of an inch at the back; and the flare of the seat-sides is such as to make them from $2\frac{1}{2}$ to 3 in. wider at top than at bottom. The front end of the seat-side is usually beveled back from one-half to three-quarters of an inch, and the back from 2 to $3\frac{1}{2}$ in. The seat-panels are from one-half to three-quarters of an inch thick, and ash blocks are glued in at the corners.

Woodwork of Gearing.—For the woodwork of the gearing the best qualities of timber should be selected, using elm or locust for the hubs, and second-growth hickory for the spokes, rims, side-bars, cross-bars, head-block, reaches, spring-bars, axle-beds, and thills. The dodge commonly given to the spokes of buggy-wheels is three-eighths of an inch; and the dish, when tired, varies according to the size of the wheel, from three-sixteenths of an inch, the standard for the lightest, up to half an inch for the heavier. The average height of buggy-wheels is 3 ft. 10 in. for the front, and 4 ft. $\frac{1}{2}$ in. for the back. Arch the axle-beds about half an inch. Either a single or double reach may be used, connecting the axles; but the double reach, as shown in the accompanying plate, is the standard for

square-box buggies: dimensions, seven-eighths of an inch wide by three-fourths of an inch deep, and of sufficient length to make the distance between the springs an inch and a half greater than the length of the body for half-elliptics, and 4 in. longer than the body when full elliptics are used. The object of using this double reach is to avoid extra weight in the other parts, and to make the gearing more secure throughout, iron being entirely dispensed with excepting in the head-plate connection, the back coupling, and the two short side-stays. The front ends of the reaches are framed or mortised into the head-block, where they are secured by a plate; and the back ends are secured by the two stays already mentioned and by couplings.

SUSPENSION.—The body illustrated is hung on side-bars, as is now common with vehicles made with half-elliptic springs. The bars are made of the best second-growth hickory, locust, or ash, and secured to the half-springs by clips. The length of the bars is measured from the outer sides of the springs, and 1½ in. is added to each end to allow for finish: width of bar at centre, 1½ in.; depth, 1¼ in. at centre, tapering to 1 × ⅞ in. at the ends, and rounded on the upper surface. These side-bars are elastic, and, in connection with the transverse cross-springs, give an easy motion, similar to that of elliptic springs, but without the recoil of the latter; moreover, with side-bars the body can be hung much lower than with elliptics.

Two cross-bars are shown beneath the body, secured to the side-bars by clips; the body rests upon these cross-bars, and is securely attached to them by bolts passing through the rockers and bars. The degree of elasticity of the side-bars depends largely upon the location of the cross-bars, which should be about 16 in. apart, and with the back bar 1½ in. nearer the back spring than the front bar is to the front spring; the centre of gravity of the loaded body being about that distance back of the centre.

The shafts, not shown in the cut, have the following dimensions: size at the cross-bar, 1¾ × 1¼ in., tapered to the front to ⅞ in., and to the back to 1⅛ in.; length forward of bar, 6 ft. 6 in.; back of bar, 14 in., curved down 10 in., the points being bent outwardly to prevent interference with the harness; distance between points, 24 in.; distance between back ends, 38 in. or more, to suit length of axle; bar, 1¾ × 1¼ in.; length of whiffletree equal to distance between shafts, outside to inside.

IRONWORK OF GEARING.—The iron parts of the gearing are few in number and simple in construction. Several varieties of king-bolts are in use, the most common being the "clip king-bolt," consisting of a stem passing through the head-block and spring, secured by a nut bearing on spring, with the clip portion encircling the axle-bed, and secured by yoke and nuts. The saddle-clips, whose shape is well known, are made with the object of securing the springs without passing bolts through the axle; and the heel-clips or couplings serve to connect the back end of the perches with the back axle-bed. The stays and steps require no special description.

For full particulars regarding the different grades of iron and steel used for carriages, and their special adaptation, see report by J. L. H. Mosier in *The Hub*, viii., 133, upon tests made by him at the Columbia College School of Mines.

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WARPING MACHINERY. See COTTON-SPINNING MACHINERY.

WASHING ENGINE. See PAPER-MAKING.

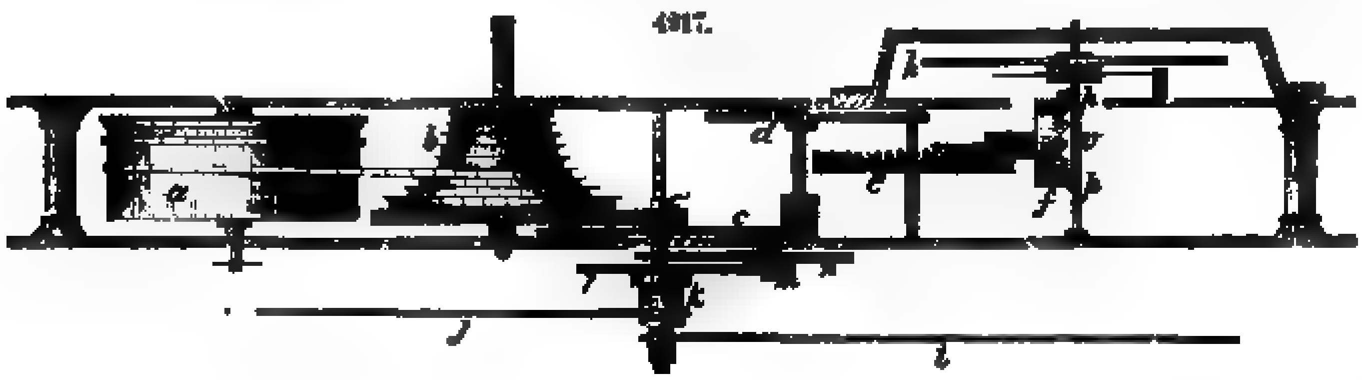
WASHING MACHINES. See LAUNDRY MACHINERY.

WATCHES AND CLOCKS.

I. WATCHES.—The train of wheels, together with the lever and balance, in a modern detached-lever escapement, such as is now made in the best watch factories in the United States and in Europe, is represented in Fig. 4216. It is placed between two plates of brass, the under one, called the pillar-plate, being an entire circle, while the upper plate, which is removed in the figure, may be either one-quarter, one-half, three-quarters, or full plate. In many European watches the upper plate is almost entirely replaced by what are called bridges—pieces which are screwed to the pillar-plate and have arms which project far enough to receive the arbors of the wheels. The barrel *b*, which contains the main-spring, has the great wheel placed around it, instead of being placed upon a fusee and driven by a chain wound upon the barrel, as represented in Fig. 4217, and which is still the construction in most English watches. Of course the tension of the spring becomes less as it uncoils; but if the coil is of considerable length, the variation need not be great, and by the nice adjustment of the balance is completely counteracted. One end of the spring is attached to the barrel-arbor, the exterior portion of which is shown at *a*, and squared, to admit of winding by a key. The other end of the spring is attached to the inner surface of the barrel. The arbor carries a ratchet-wheel, which is prevented from turning back by a click. The centre-wheel *d* is driven by the action of the great wheel upon its pinion *c*, called the centre-pinion. The centre-wheel drives the third wheel *f* by means of its pinion *e*, and the third wheel again drives the fourth wheel *h*, which carries the seconds-hand, in a similar manner. The fourth wheel drives

4216.

4217.



the pinion *i* of the scape-wheel *j*, whose teeth again alternately lock and impel the pallets *l l*, which are placed on the pallet-arms of the lever. The lever turns upon the pallet-arbor *k*, and by means of the fork gives an impulse to the balance-wheel, as has already been described. If the fourth wheel, which revolves once in a minute, has 64 teeth, and the pinion of the scape-wheel has 7 leaves, that wheel will turn round once in 6$\frac{9}{16}$ seconds; and if it has 15 teeth, each tooth will escape every $\frac{7}{16}$ of a second, and consequently there will be one complete oscillation of the balance-wheel every $\frac{7}{16}$ of a second. If the pinion of the fourth wheel contains 8 leaves, and there are 60 teeth in the third wheel, the latter will make one revolution in 7½ minutes. Again, if the pinion of the third wheel has 8 leaves, and the centre-wheel has 64 teeth, the latter will revolve one-eighth as often as the third wheel, or once in an hour. It is not necessary that these proportions should be fixed, but the number of teeth in the train must be such that there will be a certain ratio between the number of teeth in the centre-wheel, which revolves once in an hour, and the number of leaves in the pinion of the fourth wheel, which revolves once in a minute; and the teeth in the fourth wheel, the leaves in the pinion of the scape-wheel, the teeth in the latter, and the vibrations of the balance-wheel, must have certain relative proportions to each other. The hour-hand is moved by a train of two wheels and two pinions, placed on the outer side of the pillar-plate, and beneath the dial.

4218.

The arrangement is represented in Fig. 4218. The cannon-pinion is placed on the arbor of the centre-pinion, and fits spring-tight, so that it may be moved at pleasure in setting the minute-hand. Above the pinion proper there is a barrel upon which the minute-hand is placed. If the cannon-pinion, which is here hid from view, has 12 leaves, and the wheel into which it pitches has 42 teeth, the latter will revolve once in 4 hours. If, again, the pinion of this wheel

has 14 leaves, and the centre-wheel has 42 teeth, the latter will revolve one-third as often, or once in 12 hours. One of the modern arrangements for winding and setting the watch (stem-winding) is also represented in this figure. A crown-wheel is placed upon the end of a shaft which passes through the stem. This wheel moves another, which is placed upon a yoke between two other wheels, one of which, the winding wheel, is held in gear by a spring, and the other, the setting wheel, thrown into gear at pleasure by the pressure of a button. When one wheel is thrown into gear, of course the other is thrown out, so that the winding of the watch and the setting of the hands are done independently and without interference. An inspection of the figure will afford all the explanation that could be given in words.

The Watchmaker's Lathe.—A lathe especially adapted for use in the operations of watch-making is represented in Fig. 4219. It is manufactured by the American Watch-Tool Company of Waltham, Mass., and is remarkable for the beauty and accuracy of its construction, which will readily be understood by reference to the engraving. The hollow spindle and spring-chuck, and double taper bearings on the spindles, are used. The cone pulley on the head-stock is reversed to give more strength to the front bearing standards, and to allow the index-pin to be put in the back standard away from chips and dirt. The head-stock, tail-stock, and all fixtures are secured to the bed by bolts and eccentrics.

Among the attachments to this lathe are the jeweling rest, Fig. 4220, which is used for placing jewels in plates or settings. When made with calipers, it measures each jewel separately and turns a recess to fit. The universal head is represented in Fig. 4221, and Fig. 4222 shows the pivot-polishing fixture. The latter is used for grinding and polishing conical pivots, snailing, and drilling. The circular base being graduated into degrees, it can be set to grind at any angle. Fig. 4223 represents the "wigwag," which is used for polishing the staffs, pivots, and shoulders of pinions, balance-staffs, pinion-leaves, etc.

II. Clocks.—The term *clug* or clock originally meant the stroke of a hammer on a bell or gong, which gave out the time determined by the horologe or time-keeper; but at the present day it is the generally accepted designation of all stationary time-keepers, whether silent or striking.

The modern clock consists of a train of wheels driven by a spring or weights and an escapement controlled by a pendulum. The latter may be circular and balanced on pivots, and brought to a

state of rest by a finely coiled spring; or it may be a rod suspended by a delicate spring and a heavy bob at the bottom, and brought to rest by its own gravity. In either case the force applied is only so much as is necessary to overcome the friction of the train, and keep the pendulum up to the arc of vibration determined by the plan of escapement.

The difficulties that beset the seeker after fine time-keeping are so varied that they can hardly be enumerated; but a few of the more prominent ones are the unequal power applied by coiled springs, the variation in friction caused by deterioration in oil, the changes in temperature, and in tower clocks the actions of storms. The difficulties are not so great but that they can be overcome, but the problem is to do it cheaply, and do the work by machinery.

The great aim of all escapements has been to impart an unvarying impulse to the pendulum, regardless of all outside influences. This led the thoughts of horologists to *remontoirs* or re-winding, that is, to introducing a spring or weight between the scape-wheel and train, or between the scape-wheel and pendulum. These were "armed" from 1 to 60 times a minute by the train, and each gave off their own inherent power to the pendulum. This idea was modified in a thousand ways, and was very pleasing in theory, but never was fairly successful in practice.

Fig. 4224 represents Hooke's recoil escapement. When the pendulum swings to the left, it lifts the pallet *a* from the upper face of the tooth *t*, which has now passed by, while the pallet *b* has also moved to the left, meeting the tooth *t'*, and by the momentum of the pendulum producing a recoil until it returns and allows the tooth to move on. At the same time an impulse is given to the pallet *a*, the pendulum swinging to the left until the pallet is brought within reach of the tooth *c*, which strikes it before the pendulum has attained the limit of its vibration, thus producing another recoil of the scape-wheel, which lasts until the pendulum begins to return and lift the pallet away.

Graham's dead-beat escapement is represented in Fig. 4225. When the pendulum swings to the right, the tooth *a* escapes from the pallet *b*, while the tooth *c* is brought against the pallet *d*; but a portion of the exterior surface of this pallet, and also the interior surface of *b*, are arcs drawn from

4224.

4225.

4226.

the centre *e*; and upon being struck by the teeth of the scape-wheel in the direction of *e*, no recoil is produced, neither is there any impulse given to the pallet until the pendulum swings far enough to the left to bring the tooth upon its impulse face.

Fig. 4226 represents Lepaute's pin-wheel escapement, often used in tower clocks. It will be observed that the pallets may be made to receive the pins at any part of the revolution of the wheel by changing their position with reference to the pendulum; and that the form of the pins and pallets may be such as either to produce a recoil of the scape-wheel or a dead beat.

Another class, called gravity escapements, have received a large share of attention from scientists, but the results were very unsatisfactory until Sir Edmund Beckett (formerly Mr. E. B. Denison) perfected the double three-legged gravity, which with a 1½- or 2-seconds pendulum has proved very successful. In this escapement the train ends with a wheel having six legs, three of which are far enough behind the others to place a three-leaved pinion between. The pendulum swings directly in front of the scape-wheel, and is suspended just the diameter of the wheel above it. On each side of the pendulum, at its point of suspension, hangs a gravity-arm, which extends the same distance below the scape-wheel pivot that it is suspended above it, and ends with a pin that rests against the pendulum to give the impulse. These arms are bowed out at the centres so far that pallets placed on the front of one and on the back of the other shall arrest the legs of the scape-wheel in their flight. These pallets are placed at an angle of 90° from the suspension of the arm and the scape-wheel pivot. In action, when the pendulum moves to the right it meets with no resistance until near the end of its vibration, when it comes in contact with the right gravity-arm, which it raises far enough to release the leg that rests on its pallet. The scape-wheel instantly takes a run of 60°, and at the same time the three-leaved pinion carries back the left gravity-piece to its "armed" position, and locks it there by the leg of the wheel catching on its pallet. The right arm, being free, follows the pendulum down to about zero, giving an impulse according to its weight, by which time the pendulum meets the left arm, releasing the scape-wheel, when it is instantly carried back and locked, leaving the left arm free to follow down the pendulum and give its impulse. A friction-fly is placed on the scape-wheel staff, to prevent too rapid runs. In this escapement the impulse remains constant, no matter what may be the eccentricities of the train, the weight added, or outside influences;

and it would no doubt supersede all others but for the fact that, the scape-wheel turning with six vibrations of the pendulum, it requires a train of ten times higher speed than the Graham or pin escapement, which makes the train very sensitive to the slightest obstructions, besides requiring an enormous weight to arm it in time to meet the vibrations of a seconds pendulum.

4227.

The Clock Train.—It will now be proper to describe the train of wheels and principal parts of a clock. The train comprises those wheels through which the motive power, the weight or spring, exerts its force upon the pallets connected with the pendulum. These wheels are made to act upon each other by means of pinions, which are a kind of small cog-wheels. The cogs on the wheels proper are called teeth, while those of the pinions are called leaves. The axis upon which a wheel or pinion turns is called the arbor. The train of wheels in a good modern eight-day clock generally consists of four. In Fig. 4227, *a* is the first or great wheel, upon whose arbor is the barrel over which the cord passes to which is suspended the weight. The second or centre wheel, *b*, whose pinion *c* is driven by the great wheel, always turns round once in an hour, and is therefore made to turn the minute-hand. It drives the pinion *e* of the third wheel *d*, which again drives the pinion of the scape-wheel *f*. This last is the fastest-going wheel in the train, and is the one that acts upon the pallets connected with the pendulum. The usual number of teeth in the scape-wheel is 30, and if the pendulum is 39.1 inches in length, it will revolve once in a minute, because one tooth will escape at every double vibration (sometimes called a complete vibration), or every two seconds. If the pinion has 7 leaves, and the third wheel, which drives it, has 56 teeth, the latter will revolve once in 8 minutes; and if its pinion has 8 leaves, each leaf will pass a certain point every minute, and therefore, if the centre-wheel has 60 teeth, it will revolve once in an hour. If the pinion of the centre-wheel has 8 leaves, and there are 96 teeth in the great wheel, the latter will turn round once in 12 hours. This arrangement existed in clocks before the use of the minute-hand, but wheels separate from the train have since been used to move the hands at the proper rate. In the engraving a back view of the wheels is given, not placed in relation to each other just as they are when in actual use, but every wheel, following in order from below upward, placed behind its predecessor, for the purpose of showing the pinions. The wheels may be arranged in this way, but they are generally placed alternately in front of and behind each other, for economy of space. The second wheel, as has been stated, moves the minute-hand. The pinion by which the great wheel drives it is called the centre-pinion. This is on the back side of the wheel, but it carries another pinion in front, called the cannon-pinion, which is placed on the arbor so that it may be turned by using a certain amount of force, an operation which is required in setting. It is upon a tubular barrel of this cannon-pinion that the minute-hand is placed. The cannon-pinion has a certain number of leaves, which play into a wheel having, we will say, four times as many teeth, which latter has a pinion with a certain number of leaves which again play into another wheel having three times as many teeth. This wheel, called the hour-wheel, will then turn round once in 12 hours, and upon its barrel, which is placed over the cannon-pinion, the hour-hand is fixed. The time during which a clock can be made to run from one winding to another, measured by the number of times the scape-wheel can be made to revolve, depends upon the number of teeth in the train of wheels, the distance through which the weight falls, and the length of the pendulum. The number of teeth may be regulated by the number of wheels in the train, or by the number of teeth in each wheel and pinion. If the weight falls through a small space, the number of teeth must be increased, and this is usually done by increasing the number of wheels, which again requires the gravity of the weight to be increased. The number of teeth in the train remaining the same, the duration of running may be increased by increasing the distance through which the weight falls.

Tower Clocks.—To Sir Edmund Beckett (Denison) must be awarded a very large share of the credit for the perfection and accuracy attained in present tower clocks; for until the advent of the Westminster clock, described hereafter, no tower-clock maker would guarantee a clock to vary less than a minute a month. Guarantees are now freely made that the variation will be less than 15 seconds in the same period. Fig. 4228 represents a tower clock which combines all of the modern improvements, made by the Seth Thomas Clock Company. The principal parts are referred to by numbers as follows: The frame is 78 in. long, 47 in. wide, and 73 in. high. 2 is the main time-wheel, 18½ in. in diameter, with 108 teeth. The first time-pinion (3½ in. diameter, 18 leaves) gears with 4, the second time-wheel (13 in. diameter, 128 teeth). This, by the second time-pinion (2 in. diameter, 16 leaves), engages with 6, the third time-wheel (8¾ in. diameter, 120 teeth). The third time-pinion (1½ in. diameter, 16 leaves) engages with 8, the fourth time-wheel (5 in. diameter, 100 teeth). There is a fourth time-pinion, 1 in. in diameter, with 20 leaves. 10 is the scape-wheel, with six legs, each 6 in. long. At 11 are the scape-wheel fans, 2 × 10 in. each; at 12, the gravity-arms, 24 in. long. 13 is the time-barrel, 8 in. diameter, 12 in. long; 14, time winding-wheel, 16 in. diameter, 90 teeth. The winding pinion is 5 in. diameter, with 27 teeth. 16 is the snail for counting strokes of hammer; 17, snail going in time of winding-wheel; 18, pendulum (whole length, 14 ft. 6 in.; from point of

suspension to centre of oscillation, 13 ft. 8 in.; weight of bail, 500 lbs.; whole weight of pendulum, 650 lbs.; compensation, zinc and steel); 19, stirrup for sustaining pendulum in case of accident to suspension-spring; 20, take-off gear; 21, rod running to dials; 22, dial on movement; 23, seconds-dial on movement; 24, time winding-arbor; 25, strike main-wheel, 34 in. diameter, 130 teeth; 26, first strike-pinion, 3½ in. diameter, 12 leaves; 27, second strike-wheel, 18 in. diameter, 140 teeth; 28, second strike-pinion, 2 in. diameter, 14 leaves; 29, strike-regulating fans, 12 × 14 in., arms 18 in. each; 30, locking arm; 31, lock-work; 32, hammer-tail; 33, rod to connect hammer; 34, steel cams, 22 in number, bolted on to main wheel for lifting hammer; 35, strike barrel, 14½ in. diameter, 2 ft. long; 36, strike winding-wheel, 24 in. diameter, 117 teeth (the winding-pinion is 3½ in. diameter, with 15 teeth); 38, winding-arbor. At 40 are adjustable cams for turning on and off the gas. 41 is a dial for setting cams, and 42 a lever for operating the gas-cock. The wheels (except those for winding) are all of bronze; pinions all steel, engine cut, tempered and polished. The pivots are of steel, tempered and of the highest polish. The pivot-bushings are of bronze. The pallets are jeweled with selected blood-stone. Wire rope of the best charcoal iron is used. A clock of this description can be safely guaranteed to run within 15 seconds a month, and several are now running whose total variation does not average four seconds per month.*

The great Westminster clock in London, designed by Sir Edmund Beckett (Denison), and built by the late Mr. E J. Dent, the celebrated chromometer-maker to the Admiralty of Great Britain, is probably the finest example of tower-clock construction in the world. The horizontal frame which supports the three trains is 15 ft. 6 in. long and 4 ft. 7 in. wide. The time-train is wound up once, while the hour and the quarter trains are wound twice, weekly. The great striking wheel has ten circular cams 2½ in. wide, with hardened steel faces. The cast-iron head of the large hammer weighs 780 lbs., and is lifted 9 in. vertically or 13 in. from the bell. Each striking-weight weighs nearly 1½ ton. Wire ropes half an inch in diameter sustain the weights and connect the clock with the hammers. The escapement has already been described in another portion of this article. The whole pendulum weighs 680 lbs.; its length is 14 ft. 5 in. The zinc compensation-tube is 10 ft. 5 in. long, and is made of three tubes, one within the other, and drawn together until the thickness is half an inch. The centre of gravity of the bob is about 8 in. below the centre of oscillation. Owing to the weight of the compensation-tube, the pendulum-spring is 3 in. wide, 5 in. long between the chops, and $\frac{1}{32}$ in. thick. To alter the clock less than 4 seconds, a collar is fixed on the pendulum 4 ft. 10 in. from the top to carry the regulating weights. A weight of 1½ oz. placed there will accelerate the pendulum 1 second per day. There is also a large weight of 6 lbs. fitting around the pendulum except at one side, so that it can be lifted off. If the clock is too fast, this weight is removed while the clock is being wound up until it has lost the time desired. There is no temperature error, and no barometrical error can be discovered. The reports of the Astronomer Royal show that the variation of this clock is less than 1 second per week, and that it has been only 3 seconds wrong on 2 per cent. of the days of observation.

THE WATCH-CLOCK, or time-detector, is a special form of clock so arranged as to guard against any

* The foregoing description of tower clocks has been contributed by Mr. D. W. Bradley, of the Seth Thomas Clock Company, New York.

negligence of watchmen in visiting parts of a building through which their beat extends. Essentially the device consists of a paper disk marked with the hours and suitably divided, and caused to rotate by a clock-train. This clock is carried by the watchman. At each station is a small key securely fastened, so that he must actually go there in order to use the key. The insertion of the latter into the clock causes a mark to be produced on the paper dial which indicates the time at which the visit was made, how long a period was occupied in going from one station to another, whether the man visited the stations in regular order or not, etc.

4229.

In Buerk's detector a number of sliding bars are connected with pricking points, so that by turning the key the ward on it strikes a certain bar and perforates the dial paper. The key belonging to one station cannot be used for another.

Imhauser's detector is represented in Fig. 4229. Four of the keys used are shown above the device. The insertion and turning of the key, instead of causing a hole to be pricked in the dial, punches a figure thereon.

PNEUMATIC CLOCKS.—Clocks operated by compressed air have been in use in Vienna for some years past. Their construction is quite simple, and their operation accurate. They are based on the principle that if a column of air, inclosed in a tube at a given tension, be subjected to pressure, it immediately transmits that pressure to all its parts, even the most remote. But the compressed air, after having exerted its force, must be expelled from the tube and replaced by a fresh column; because, if the tube were not alternately opened and closed, this column would act precisely like an elastic spring; consequently the mechanical effect on the pistons would be insignificant, and the hands of the clock would remain at a standstill, powerless to move. The pneumatic clocks are at once simple and perfect, they are not likely to get out of order, and even the escape of air from the distributing pipes cannot alter their movement. The mechanism may be described as follows: Air is injected into a mechanical cylindrical reservoir, *M*, Fig 4230, by means of a hydraulic motor; from thence this air is led into another large cylinder or distributer, *D*; it is only used, however, as fast and in such quantities as needed by the regulator. At every minute the air from the regulator enters the lead or iron distributing pipes, and acts on a leather piston inclosed in a small cylinder attached to a lever; and the latter determines the movement of an escapement that moves the hands of the receiving dial *H*. This lever receives the pressure communicated by the central motor *R*, and at every movement causes an escapement-wheel to advance one notch, marking one minute of time. At every unlocking of the escapement-wheel, the air from the distributer ceases communication with the distributing pipes, and escapes into the atmosphere. The regulator of the central motor *R* is an endless-chain clock as perfect as possible, furnished with a compensating pendulum. This receives astronomical time from the public observatory, and transmits it to the dials, distributed in different quarters of the city, as well as to those of private dwellings. In order to prevent any accident, and as a simple measure of precaution, each central station is provided with twin motors, each complete in all its parts, and only one of which is in operation at a time. These two motors are connected automatically, in such a way that if, through an accident, the working machine suddenly stops, the other one at once begins operation, thus preventing the least retardation in the movement of the clocks. These clocks are so constructed that they must work perfectly or not at all; there is no alternative. The invention is due to Mayrhope, an Austrian engineer; but the merit of perfecting it belongs to M. Victor Popp.

ELECTRIC CLOCKS.—About the year 1840 Prof. Wheatstone exhibited to the Royal Society of London a clock-dial, the hands of which were moved by a wheel acted upon by a small electro-magnet at intervals, the current being formed and broken by means of the oscillations of the pendulum of a common clock. Through this device the same time may be indicated in several distant places simultaneously In 1848 successful experiments were made upon this principle by the United States Coast Survey between Cincinnati and Pittsburgh, a distance of 400 miles. A clock placed in the electric circuit recorded its beats at all the offices along the line by means of Morse's apparatus. The first clock, however, which had any of its own parts moved by electricity, was constructed by Alexander Bain of Edinburgh. In this electricity was used as a motive power in place of the usual weight or spring, and the pendulum was not only employed as a regulator, but as a motor. The bob of the pendulum was formed of a coil of wire which became a magnet at intervals of the oscillations, and, passing over the poles of permanent magnets placed near the ends of the arc of oscillation, was alternately attracted by each. In some of the clocks the two magnets were temporary, and the reversal of their poles by one of the devices used in electrical apparatus caused an alternate attraction and repulsion of the pendulum. Mr. Shepherd exhibited at the International Exhibition in London of 1851 a clock in which there was an electrical gravity escapement, the pallets being raised by temporary magnets. A description of it may be found in Wood's "Curiosities of Clocks and Watches," and also in Sir E. B. Denison's treatise.

The New York Time Service, under the direction of Mr. J. Hamblet, has introduced a system by which clocks may be kept constantly under the electrical control of a central regulator or standard clock, which is kept in exact time with the clock of the National Observatory in Washington. The central regulator is stationed in the Western Union Telegraph Company's Building in New York, and is so constructed as to keep time with the highest attainable accuracy. In addition, it is every day compared with the clock of the National Observatory, and checked by the daily time observations made at the observatories at Allegheny, Pa., and Cambridge, Mass., with which it is in telegraphic

4330.

PNEUMATIC CLOCK.

connection. By this it must not be inferred that the clock in question is kept in exact accord with either or all of the observatory clocks, that being a mechanical impossibility. The range of variation, however, is kept within a few hundredths of a second. Fig. 4281 will make clear how it is done. It shows a section of the paper tape of the chronograph, which is used in comparing the standard clock with the clock of the Washington Observatory. The chronograph is electrically connected with both clocks, and records the pendulum-beats of each on the strip of paper. If the beats are exactly synchronous, the dots stand side by side. If the beats are not synchronous, the dots will be separated by an interval, long or short according to the difference of the clocks—that is, the difference in time between the beginnings of corresponding beats—and the speed of the chronograph.

4281.

Supposing the clock to be beating seconds, and the chronograph to discharge an inch of tape each second, it is obvious that the dots recording the beats of each clock will stand one inch apart. It is obvious, too, that the lineal space between the recording dots of two clocks not beating exactly together can easily be measured, as shown by the scale placed below the dots in the cut (Fig. 4281), and thereby the difference in time exactly determined.

The next step in the time service is to distribute the accurate time thus maintained to such as want it, which is done through an electrical attachment to the standard clock. This controlling clock was constructed by E. Howard & Co. of Boston, from designs by Mr. Hamblet, and has a Denison gravity escapement. The front clock-plate and the electrical mechanism are shown in Fig. 4282. The wheel in the centre with the seconds-hand revolves once a minute. One of its 30 teeth has been filed away, the vacant space causing the omission of the tick which would otherwise mark the 58th second of the minute. The remaining teeth act upon a delicate jeweled spring, which breaks an electric circuit at the passage of each tooth. The two wires connecting with this spring and its banking operate the relay, at the left of the figure, and through it the sounder, which indicates the beginning of each minute by a pause of two seconds. The beginning of each 5 minutes is identified by a pause of 20 seconds, obtained through the agency of the 5-minute wheel to the left of the seconds-wheel. At each revolution of the 5-minute wheel the lever at the top drops into the notch in the wheel, making electric connection between the two wires governing the relay, thus preventing the minute-wheel from breaking the circuit for the space of 20 seconds. At the right near the top of the figure is shown a sounder, which may be located at any point on the line. It is by means of these sounders, with which the recipients of the service are supplied, that their timepieces are regulated. (See *Scientific American*, xxxix., 335.)

WATER-GAUGE. See Boilers, Steam.

WATER-METERS. Apparatus for the measurement of water. In general terms they may be divided into two classes: 1, the positive; 2, the inferential. To the first class belong all forms of piston-meters, whether reciprocating or rotary; to the second, propeller-wheels, rotating vanes, or similar devices propelled by the current, and indicating the flowage by the rate of revolution. The distinctive difference between the two is, that the positive meter measures water by means of a chamber alternately filled and emptied, so that the flow of water ceases when by any derangement the motion of the piston is interrupted; while neither the motion nor the stoppage of the inferential meter has any effect upon the water delivery, so that at times a large amount of water may pass unrecorded. Another important mechanical difference is, that the motion of a piston-meter is slow, while that of the inferential wheel is rapid; and this has much to do with their relative durability.

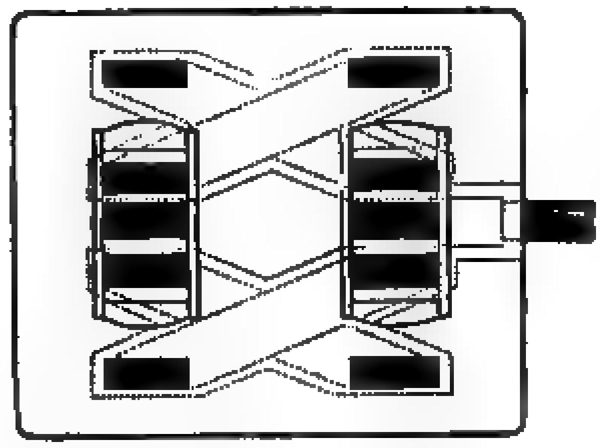
A very excellent résumé of the whole subject of water-meters, by Mr. Phinehas Ball, will be found in *Engineering News*, vi., 334 *et seq.*, from which is taken the following discussion: "Three problems have taxed the inventors of a rotary meter to the utmost: 1st, to reduce the friction of the moving vanes or wheel to the lowest possible point; 2d, to so direct the current upon the wheel that it would move with the least possible quantity of passing water; and 3d, to so construct the register that it should retard the motion of the wheel as little as possible. The moving wheel of a rotary meter can yield only a small amount of power, and hence little can be expended in driving the register without decreasing its reliability. But, however delicate and carefully adjusted a register may be, it never can be made to move without the application of an adequate amount of power. This is a fixed fact; and next, friction is ever present, and to move the meter at all the force of the flowing current of water must be greater than these two opposing forces. Below this point water must pass the meter without being registered, there being no contrivance of valves or other mechanism to prevent it; the case being the same as with a turbine water-wheel, where the gate must be opened beyond a certain point before the wheel will begin to revolve."

Double Reciprocating-Piston Meters.—Water-meters constructed on this principle are positive in their measurement. Regarding these meters Mr. Ball says: "As in the steam-engine, having cylinders of a given capacity with pistons arranged for a definite length of stroke, the admission of the water to

the cylinder and its discharge therefrom being regulated by properly-adjusted valves, controlled and actuated by suitable devices, the action of the meter becomes, in fact, the same in result as the measuring out of a specific quantity of any liquid in a gallon or other definite-sized measure, and recording the number of times the measure used has been filled and emptied. This result is accomplished in the use of a water-meter by the automatic movement of the pistons in the cylinder produced

4233.

4234.



by the pressure of the flowing water, by converting the fixed quantity passing the cylinders at each stroke of the pistons into cubic feet or gallons, and recording the same by suitable mechanism. The meter is moved by the force of the water due to the head under which the water is drawn, and hence this form of meter acts with power, the same as is the case with the common piston steam-engine."

4235.

The Worthington Meter.—Mr. H. R. Worthington of New York was one of the first to construct meters of this class, and to demonstrate their superior efficiency. His meter, which is very largely used in nearly all the principal cities of the United States, is represented in Figs. 4233, 4234, and 4235. Fig. 4233 shows the apparatus with the casing broken away to exhibit the interior construction; Fig. 4234 shows the arrangement of valves, ports, and water-passages; and Fig. 4235 is the bottom plate. The working parts of this machine consist of two hollow brass plungers made very thin, light, and air-tight, to secure their flotation. They work through brass packing-rings, and act reciprocally each upon the valve of the other, in such a way as to produce a motion that is positive

4236.

under all conditions, combined with an absolute steadiness of delivery, whether the stream be large or small. The working parts are few, and, excepting those that pertain to the connecting gear, there are no rotary or oblique motions. The details of its construction have been gradually reformed by

the teachings of long practice, until now the machine seems to be in a condition to meet every reasonable requirement. A recent trial made of one, after eleven years' constant service in the Croton Department of New York, gave a result within 1½ per cent. of absolute correctness.

The Ball and Fitts Reciprocating-Piston Meter, manufactured by the Union Water-Meter Company of Worcester, Mass., is represented in Fig. 4236. The chief peculiarity of this meter is in its having but one valve to do all the work of admitting, discharging, and regulating the flow of the water to and from the four cylinders. The valve is a rotary conical valve, having ports so arranged that when they are opened by the revolution of the valve on its axis, the admission and exit of the water to and from the cylinders is made gradual, and the usual reaction by the cut-off of the ordinary valve avoided. The travel of the pistons being controlled by the stops, while the length of the stroke is fixed by the length of the crank, the measurement of the meter is made very accurate under all variations of head and size of stream. This is evident, because the valve cannot revolve at a less distance in the travel of the pistons than is sufficient to pass the cranks over their centres, and they cannot go beyond the proper length of the cranks, being arrested by the stops. This feature is claimed to insure accurate measurement under varying heads of pressure and size of stream.

SINGLE-PISTON METERS.—Meters of this class use but one cylinder, one piston, and one valve. The valve is closed by the action or motive power of the piston, but is thrown over usually by a bob-weight, or the action of a spring or other equivalent device. This form, in appearance, is much more simple than the double piston, but is in reality more complicated by reason of the extra devices needed to actuate the valve. A spring has at best only temporary value, while the fall-weight, though more lastingly reliable, is usually more cumbersome to the machine in use. To obviate the difficulties that attend the use of a fall-weight or a spring, many devices have been proposed, in which a sort of secondary small piston-valve is used to actuate the main valve, after it has been closed by the piston. This, though different in form, in effect converts the single reciprocating piston into the double piston. One peculiar action of the ordinary single-piston meter is, that it cuts off the current of flowing water fully and completely at every change of stroke. This is inevitable from the necessity under which the current is reversed by the valve, and consequently the stream is intermittent, and has a decided reaction on the supply-pipe.

DIAPHRAGM METERS.—In these meters the cylinder and piston are replaced by a flexible movable diaphragm. The measuring is done by filling and discharging water from the cavity formed by the movement of the diaphragm. In this class there is all the accompaniment of valves and the devices for moving the valves as in the piston meters. They are made with double and single diaphragms after the style of the respective piston meters, the valves in each class being actuated in a similar manner as its respective class of piston meter.

4237.

A good example of a diaphragm meter of improved construction is given in Fig. 4237, which represents the meter invented by Mr. William B. Mounteney of Chicago, Ill. Fig. 4237 is a side elevation, partly in section, and Figs. 4238, 4239, and 4240 represent details not clearly shown in the first. The upper part of the meter-chamber receives the water from the supply-pipe, and contains the levers that actuate the registering mechanism and the rotary valve *C*. The lower portion of the meter is divided into four compartments by a central rigid partition and the two flexible diaphragms *A*. The latter are placed between concave metallic diaphragms *a*, which are slotted to insure the easy detachment of the rubber diaphragm, and to agitate the water so as to prevent the accumulation of sediment. The rubber diaphragms are connected with the arms of the rock-shafts *B*, and the latter extend into the upper or receiving chamber through a simple and effective stuffing-box, and are provided with arms which connect by links with a crank on the shaft of the valve *C*. The registering mechanism at the top of the casing receives its motion from the crank on the valve-shaft, and accurately records the oscillations of the diaphragms, and consequently indicates the amount of water consumed. The entrance and eduction of water to all of the compartments are controlled by the rotary valve *C*, which is operated by the diaphragms through the medium of the shafts and levers already described. The water under pressure is alternately conducted to and allowed to flow from opposite sides of the pair of diaphragms, so that both diaphragms are made to traverse alternately backward and forward as the chambers are alternately filled with a measured quantity of water, which will be accurately indicated by the index and dial of the registering apparatus.

ROTARY-PISTON METERS.—This class is of recent design and introduction. Unlike all other rotary meters, the revolving pistons are used in duplicate, and interlock each other, so as to form a contin

uous revolving diaphragm or abutment between the inlet and outlet ports, in the same manner as the piston in a steam- or water-cylinder forms a complete dam or dividing abutment between the ports of the inlet- and exhaust-valve. The moving parts acting both as valves and pistons, no separate valves or pistons are required.

The rotary-piston meter is the invention of Benaiah Fitts, and manufactured by the Union Water-Meter Company of Worcester, Mass. Fig. 4241 represents the exterior of the apparatus, and Fig. 4242 shows the working parts removed. The pistons are made in concentric circles and interlock with each other in revolving, in such manner that a free passage for the water through the meter is always as effectually closed as is the passage through the reciprocating-piston

4241.

4242.

meter. The pistons turn on fixed centres, and are guided and controlled in their revolutions by elliptical gears attached to the part of the piston that revolves on the fixed shaft. The water, through the continuous movement of the pistons, passes through the meter in an unbroken stream. It is claimed that all reaction in the form of water-hammer or other disturbance in the service-pipes is prevented, and that the delivery is unaffected by the working of the meter. The apparatus is noiseless in its movement, delivering the same quantity of water as with the pipe to which it is attached, when the opening in the meter equals that of the service-pipe. The revolving pistons being made so as not to touch any portion of the case in which they are fitted, and the joint being left free, it is claimed that there is consequently no wear upon any portion of the moving parts, except on the step upon which the pistons are hung. The wear of the step is provided for by the use of a metal peculiarly adapted to withstand revolving abrasion. The durability of the meter in actual service, and the accuracy with which it retains its quality of measurement, are shown by the results of the accompanying recorded tests furnished by the manufacturers:

Results of Tests of Five-eighths Rotary-Piston Meter No. 6019, after passing 538,802 Cubic Feet of Water = 4,030,238 Gallons. Tests made by I. P. K. Otis, February 4, 1879.

Pressure of Water on Meter, 65 lbs. per Square Inch.

TIME.	Cubic Feet on Register.	Actual Cubic Feet Run into Tank.	Size of Stream.	TIME.	Cubic Feet on Register.	Actual Cubic Feet Run into Tank.	Size of Stream.
4 m. 40 s.	10	10.20	Full.	1 h. 13 m. 20 s...	10	10.40	.08
9 m. 40 s.	10	10.00	20	2 h.	10	10.80	06
41 m	10	10.80	.10				

Inferential Meters (*measuring a fractional part of the stream passing a given pipe or a given orifice*).—These meters have been planned on the principle of the uniform flow of water through pipes and orifices under known conditions of pressure; the arrangement being to divert a certain proportion of the water passing in the main pipe, and, by measuring accurately the small stream diverted, infer the larger quantity. The small quantities named in the patented devices have been one-sixteenth, one-hundredth, and one-thousandth part of the whole Meters of this class display much ingenuity in design and construction, but, according to Mr. Ball, no device has come to any extent into practical use.

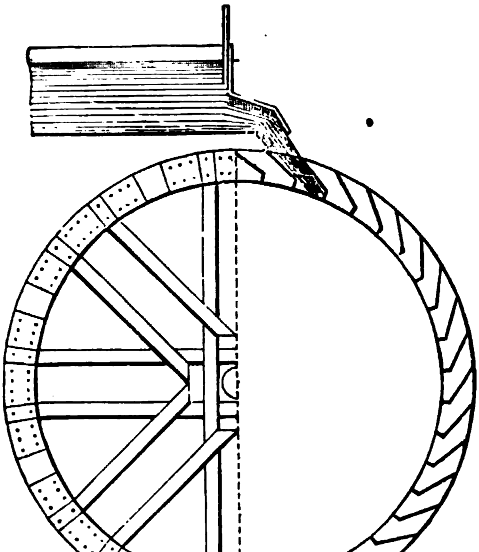
Miscellaneous Meters.—A few inventions have been arranged under this head, their form and parts being such that they do not belong to any one of the foregoing classes. In this division are to be found a few very singular devices. One is a flexible tube through which the water passes to the outlet, over which pass a series of rolls, which as they pass press down the tube, the roll forming a kind of exterior piston and moving-valve combined. This will produce very accurate results; but no substance can be found that will sustain the wear of the passing rolls for any great length of time.

WATER-WHEELS. The work of water-wheels is done by the force of gravity acting on water. The total work in a fall of water is expressed by the product of the weight of water and the height of the fall; and in order that the whole of this work shall be realized by the wheel, the water must enter the machine without shock and leave it without velocity. There is, however, unavoidably a residual velocity, and the loss of work due to this is expressed by the equation, $w \frac{v^2}{2g} = w h'$, in which w represents the weight of water, v the residual velocity, g gravity (see DYNAMICS), and h' the head due to the residual velocity. The part of the head expended in effective work and upon internal resistances is therefore $h - h' = h - w \frac{v^2}{2g}$, in which h represents the height of the fall.* There are two classes of water-wheels: first, those which turn on a horizontal axis; second, those which turn on a vertical axis. To the first class belong undershot, overshot, and breast wheels; to the second class, the tub-wheel, the Barker and the Whitelaw water-mills, and the turbines. The last constitute at the present time the most efficient variety of water-wheel, and are probably the most numerous. They are therefore separately discussed under WATER-WHEELS, TURBINE.

WHEELS TURNING ON A HORIZONTAL AXIS.—Owing to the irregularities in the volume and velocity of streams at different seasons, and the loss of momentum by friction against their beds, it becomes necessary, in order to drive water-wheels, to store up water and to develop the power in a fixed position. This is obtained by constructing a weir or dam across the stream, and allowing the collected water to strike the wheel-buckets either from above, at the middle, or beneath. (See "The Construction of Mill-Dams," Leffel, Springfield, O., 1874.) The first variety is called the overshot, the second the breast, and the third the undershot wheel.

The Overshot Wheel.—The general construction of this class of wheels is shown in Fig. 4243. The water is received into cavities formed by stout planks extending between the sides of the wheel and placed at an angle or curved toward the stream. These are buckets proper, and the wheels are sometimes called bucket-wheels. According to Clark, the chief causes of loss of head are, first, the relative velocity of the water when it enters the wheel, and second, the velocity which it possesses at the moment it falls to the level of the tail-race. Such wheels answer well for heads of from 13 to 20 ft. For heads of less than 10 ft., breast-wheels are preferred. The velocity of the buckets should not be less than 3 ft. per second; it may be 6½ ft. per second for small wheels, and 10 ft. for larger wheels, without sensibly affecting the efficiency. The efficiency at a low speed may rise to 80 per cent.; but ordinarily, with velocities of from 3 to 6½ ft., the efficiency varies from 70 to 75 per cent. The capacity of the buckets should be three times the volume of the charge of water; they may be 10 or 11 in. deep, and be placed 12 or 14 in. apart. With a velocity of 4 ft. per second, 1 cubic ft. of water for 1 ft. of breadth of wheel may be consumed per second.

4243.



Breast-Wheels.—When the height of the fall is considerably less than the diameter of the wheel, the term *breast* is used to express the relation. Such a wheel is represented in Fig. 4244, and, to denote that the water is received above the line passing horizontally through the axis, it is termed *high-breast*. In order to render the low fall of water as much as possible available upon the wheel, an *arc* is usually constructed of the same radius as that of the wheel, to confine the water, and prevent it from being spilt from the buckets before it has arrived at the lowest point of the run. In the example referred to, this arc is built of hewn stone; but sometimes it is constructed of timber, and not unfrequently of cast-iron plates.

In practice the efficiency of breast-wheels reaches 70 per cent. when the height of the fall approaches 8 ft., and 50 per cent. for a fall of 4 ft. For a well-constructed wheel, slow-moving, M. Morin found an exceptional efficiency of 93 per cent. Sir William Fairbairn states that the efficiency of high-breast wheels is 75 per cent. when moving at the rate of 5 ft. per second at the periphery. The usual velocity adopted by him for high and low falls was from 4 to 6 ft. per second; for a minimum velocity, 3 ft. 6 in. per second for falls of from 40 to 45 ft.; and for a maximum velocity, 7 ft. per second for falls of 5 or 6 ft. The water should be delivered to the wheel at a low velocity; or if the velocity is considerable, the delivery should be at a tangent to the edge of the float. The most

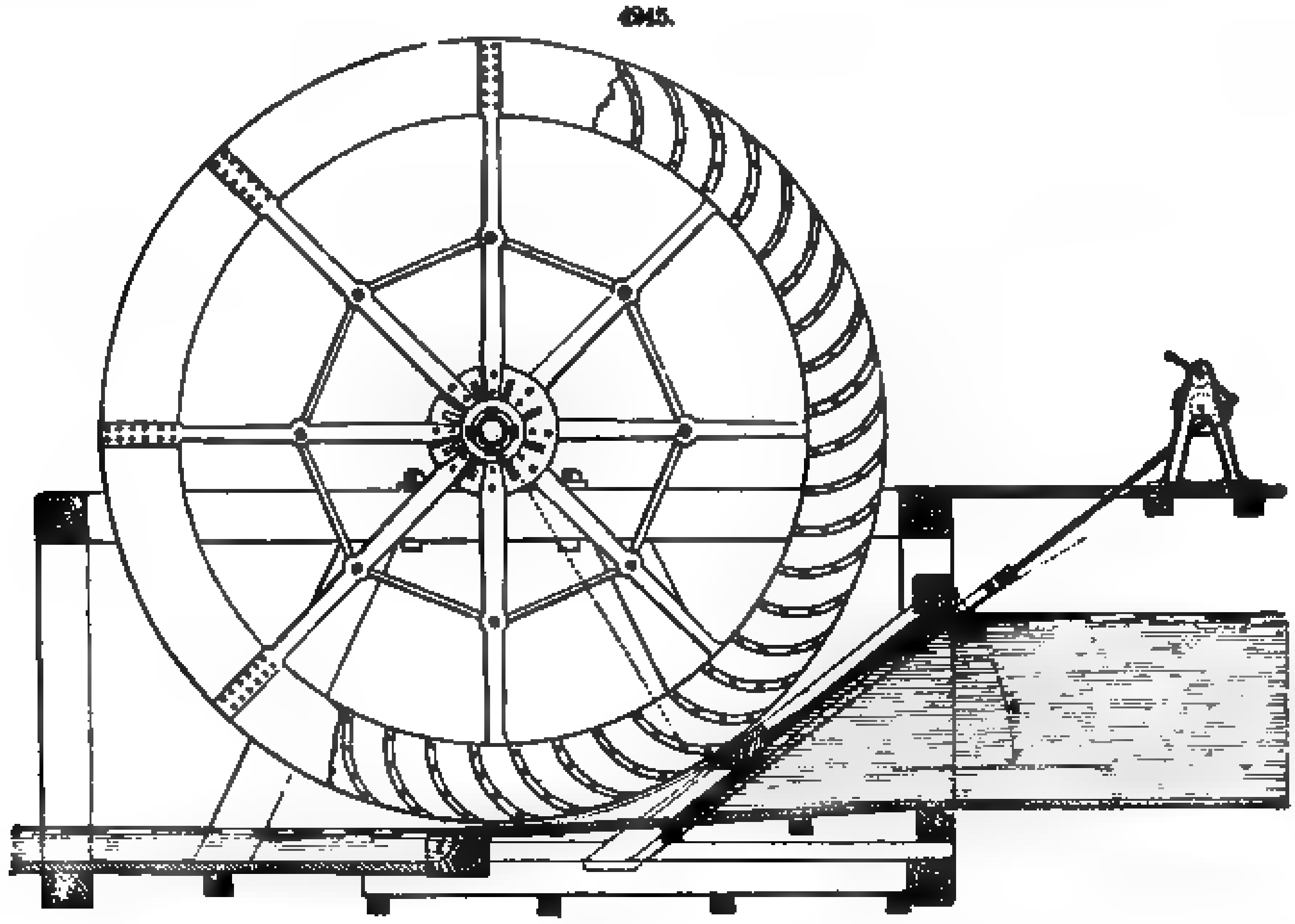
* From Clark's "Rules, Tables, and Data," &c.

suitable velocity of floats is 4½ ft. per second; the velocity should not exceed the limits of from 3 to 6½ ft. per second. The depth of water over the sliding gate should be from 8 to 10 in. measured

4944.

from still water. The diameter should be at least 11½ ft.; it is seldom more than from 20 to 23 ft. These diameters are suitable for falls of from 3 to 6 or to even 8 ft. The distance apart of the buckets should be 1⅓ to 1½ time the head over the gate for slow wheels; for quick wheels, a little

4945.



more. The depth of the buckets should be slightly over 2.3 ft. Normally the interior capacity between two buckets should be nearly double the volume of water contained there.

Undershot Wheels.—These wheels move chiefly by the direct impulse of the fluid. In construction, they differ little from the bucket-wheel, except that the buckets are usually replaced by radial floats. Water is admitted to the wheel by a sluice, which should be placed as close to the wheel as possible. The retaining cheeks of the aperture inside of the sluice should be slightly contracted, answering to the natural contraction of the stream after passing through the orifice, in consequence of the resistance which it there encounters. The sides of the course or arc in which the wheel moves must necessarily be parallel; but, immediately on passing the vertical plane passing through the axis of the wheel, the floor ought to deepen and the sides expand and leave the water as much space to diffuse itself over as possible. This arrangement is shown in Fig. 4245, as far as it is applicable with a sluice-framing entirely constructed of wood; but, when the construction is of iron, the confinement of the water may be made much more complete.

Ordinarily undershot wheels are made from 10 to 25 ft. in diameter. The floats are from 14 to 16 in. apart at the circumference, and from 24 to 28 in. deep. The maximum effect is obtainable when the final velocity of the water equals one-half that of the initial velocity; it is then 50 per cent.; 40 per cent. may be taken as the maximum in practice.

In Poncelet's undershot wheel the floats are curved—usually in circular arcs—and so placed that the hollow of the curve is presented to the entering water, the edge of the float being set at an angle of 30° to the circumference of the wheel. There are 36 floats in wheels of from 10 to 13 ft. diameter, and 48 floats in wheels of diameters of from 20 to 23 ft. If the water could enter the wheel without shock, tangentially to the floats, the velocity of the floats being half the velocity of the water, the water would ascend the float, and would then descend by the force of gravity and drop into the tail-race with a final velocity equal to zero. The efficiency under these circumstances would be 100 per cent. But the conditions of practice do not admit of a tangential entrance, and the efficiency is not more than 65 per cent. for falls of 4 ft. and less, 60 per cent. for falls of from 4 ft. 3 in. to 5 ft., and from 55 to 50 per cent. for falls of from 6 to 6½ ft. These efficiencies are materially greater than that of the undershot wheels with radial floats; and the experience of the Poncelet float conspicuously demonstrates the essential importance of providing graduated entrances and avoiding shocks, concussions, or eddies in the water. The most favorable ratio of the velocity of the floats to that of the water is 55 per cent. The distance between the inner and outer circumferences that limit the floats should be at least one-fourth of the head; Poncelet advises one-third.

Current-Wheels.—These are a variety of undershot wheel. They are usually supported in frames or rafts, which may float on the stream, and are prevented from being carried away by suitable moorings. In other forms the frame simply swings over the current. The most suitable ratio of the velocity of the floats of these wheels to that of the current is 40 per cent. The depth of the floats should be from one-quarter to one-fifth the radius, and should not be less than 12 in. The diameter of the wheel is usually from 13 to 16¼ ft., with 12 floats. The floats on the under side of the wheel should be completely submerged, their upper edges being not more than 2 in. under water.

WHEELS TURNING ON A VERTICAL AXIS.—*The Tub-Wheel.*—The old-fashioned spoon-wheel or tub-wheel consists of a number of paddles fixed on a vertical axis, revolving within a cylindrical well of masonry, with very little clearance. The paddles are slightly concave, and are struck on the hollow side by a horizontal current from a reservoir at a considerable head. The current enters the well tangentially, and, after having expended its force, falls between the open paddles to the bottom of the well. The maximum efficiency is calculated to be due to a velocity of the centre of the paddles when they are struck equal to one-third of the velocity of the current, and the efficiency is 30 per cent. In practice the efficiency varies from 15 to 30 per cent.

Barker's Mill consists of two hollow radial arms revolving on a central pipe, through which water under pressure passes to the extremities of the arms, and is ejected through an orifice at the end of each arm in opposite directions, thus producing rotary motion.

Whitelaw's Mill is an improvement on the foregoing. The arms taper from the centre toward the circumference, and they are curved in such a manner as to allow the water to pass from the radial openings to the orifices, in directions nearly straight and radial when the machine runs at its proper speed, so that very little centrifugal force is imparted to the water by the revolution of the arms, and that therefore a minimum of frictional resistance is opposed to the motion of the water. A model 15 in. in diameter, measured to the centres of the orifices, with a central opening 6 in. in diameter, and two orifices of discharge each 2.4 in. by 0.6 in., was tested under a head of 10 ft., making 387 revolutions. The efficiency amounted to 73.6 per cent. At 324 revolutions the efficiency was 71 per cent. According to the results of tests of another model mill, the efficiency amounted to 76 per cent. when the speed of the orifices was equal to that due to the height of the fall. A water-mill on Whitelaw's system 9.55 ft. in diameter, having circular orifices 4.944 in. in diameter, with a fall of 25 ft., was erected on the Chard Canal in 1842, for the purpose of hauling boats up an inclined plane. The net work done by the machine represented an efficiency of 67.3 per cent., with the resistance of the gearing in addition. It was estimated that the actual duty of the mill amounted to 75 per cent.

Works for Reference.—The foregoing data relative to water-wheels are mainly taken from "Rules, Tables, and Data for Mechanical Engineers," Clark, London, 1876. Old methods of constructing water-wheels, determining power, etc., are fully detailed in "Appletons' Dictionary of Mechanics," 1851. The various forms of water-wheels are described in Ewbank's "Hydraulics." See also Weisbach's "Mechanics of Engineering," vol. ii.; "Hydraulics and Hydraulic Motors," New York, 1877; "Hydraulic Motors," Bresse, translated by Mahan, New York, 1869.

WATER-WHEELS, TURBINE. Turbine wheels belong to the class of water-wheels which rotate on a vertical axis. The force of a head of water is applied to them by impact and reaction combined. By means of passages exterior to the wheel, the water is caused to impinge on the buckets or blades tangentially. These blades, and also the guide-channels which lead the water to them,

should be so curved as to receive the water with the least possible shock and discharge it with the minimum velocity. The size of turbines diminishes as the height of fall increases, and for falls of ordinary height they are very much smaller than the usual forms of water-wheels. Their smaller size gives necessarily a high velocity of rotation, which constitutes their most important advantage over the older varieties of wheel. It permits the adoption of lighter and less expensive machinery for transmitting power, dispenses with gearing, and gives greater regularity of speed and nearly equal efficiency under all heights of fall. The method of determining the efficiency of turbine wheels will be found treated elsewhere in this article. It is highest when their speed is between 0.5 and 0.7 of that due to the height of fall.

For designing turbines no special rules can be laid down. The most extensive investigations into the subject made in this country are probably those conducted by Mr. J. B. Francis, and fully described in "Lowell Hydraulic Experiments," Boston, 1855. From experiments on a Boyden outward-flow turbine Mr. Francis deduced the following rules:

"The sum of the shortest distances between the buckets should be equal to the diameter of the wheel.

"The width of the crowns should be four times the shortest distance between the buckets.

"The sum of the shortest distances between the curved guides, taken near the wheel, should be equal to the interior diameter of the wheel.

"The number of buckets is to a certain extent arbitrary. As a guide in practice, to be controlled by particular circumstances, and limited to diameters of not less than 2 ft., the number of buckets should be three times the diameter in feet, plus 30. The number of the guides is also to a certain extent arbitrary; the practice at Lowell has been, usually, to have from a half to three-fourths of the number of buckets. As turbines are generally used, a velocity of the interior circumference of the wheel of about 56 per cent. of that due to the fall acting upon the wheel appears most suitable."

The method of laying out buckets and designing other portions of a turbine in accordance with the above rules is fully detailed in "Appletons' Dictionary of Mechanics," 1851. A wheel constructed after these plans was tested by Mr. Francis at the Tremont Mills in Lowell, Mass., and gave a percentage at full gate of .79. Formulas also based on these rules are given in "Hydraulic Motors," Mahan, New York, 1876.

The data above referred to may be taken as guides for practice, but do not represent established proportions, for it is doubtful if any such exist. The whole subject is in its infancy, and present knowledge concerning it is not sufficient for the deduction of general conclusions. Every manufacturer is more or less engaged in experimenting for himself, and between those who have experimented most the widest differences of opinion exist. Large numbers of tests of turbines have been made in this country, and extraordinary percentages of efficiency, reaching in some cases above 90 per cent., have been obtained. Such results are not accepted by the majority of engineers. Prof. R. H. Thurston probably sums up in the following few words all that can be said in general terms on turbine designing: "The velocity of direct flow, or that with which the water passes through the wheel, is to be preserved as nearly uniform as possible, and the passages are to be given such form and magnitude of cross-section as will insure that uniformity. The velocity of the whirl is made as nearly as possible equal to the rotary velocity of the wheel, and the water is thus passed upon the wheel without shock. It should glide over the buckets without sudden change of velocity, and should finally pass out with a speed opposite in direction and equal in magnitude to that of the wheel, thus dropping out of the wheel with the least velocity of flow, and with its original *vis viva* transformed into mechanical energy."

FORMS OF TURBINES.

The turbine was introduced into general use by Fourneyron in France in 1827, and soon after by Fairbairn in England and by Boyden in the United States. Turbines are classed as outward-flow, inward-flow, and parallel or downward-flow wheels, according to the direction taken by the water in passing through them.

I. OUTWARD-FLOW TURBINES.—*The Fourneyron Turbine.*—This wheel acts with an outward flow; that is to say, the water enters from above through a central opening, and is guided by curved blades to be discharged laterally at the base of a circular chamber, equally at all parts of the circumference, into the buckets or curved blades of the wheel. The wheel is annular and closely surrounds the circular chamber. When the supply of water is insufficient for working the turbine at its full power, the exit openings from the well are partially closed by a cylindrical sluice, which is lowered upon them to the required extent. The efficiency is reduced in proportion as the sluice is lowered, for the action of the water on the wheel is less favorably exerted.

[illegible]

The Boyden Turbine, devised by Mr. Uriah A. Boyden of Massachusetts in 1844, is constructed on the same principle as the Fourneyron wheel, but differs from it in many important particulars, as follows: 1. The water is conducted to the turbine through a vertical truncated cone concentric with the shaft. The water as it descends acquires a gradually increasing velocity, together with a spiral movement in the direction of the motion of the wheel. The spiral movement is in fact a continuation of the motion of the water as it enters the cone. 2. The guide-plates at the base are inclined so as to meet tangentially the approaching water. 3. A "diffuser" or annular chamber surrounds the wheel, into which the water is discharged. This chamber expands outwardly, and thus the escaping velocity of the water is reduced. A plan of the Boyden wheel is given in Fig. 4246. Fig. 4247 represents the modern method of its construction. *A* is a quarter turn leading the water to the wheel; *B*, the lower curb; *C*, the disk carrying the guides; *D*, the wheel with its guide-channels, shown with the guide-curves more clearly in Fig. 4246; *E*, a disk con-

necting the wheel to the vertical shaft; *F*, *G*, and *G'*, supporting-beams; *S*, the shaft; *I*, the support for the bearings; *J*, the driving-gear; and *R*, the apparatus for moving the gate.

II. Parallel or Downward-Flow Turbines.—*Fontaine's Turbine.*—In turbines constructed with the downward or parallel flow, the wheel is placed beneath an annular series of guide-blades. The water strikes the curved floats of the wheel, and falls vertically or nearly so into the tail-race. The

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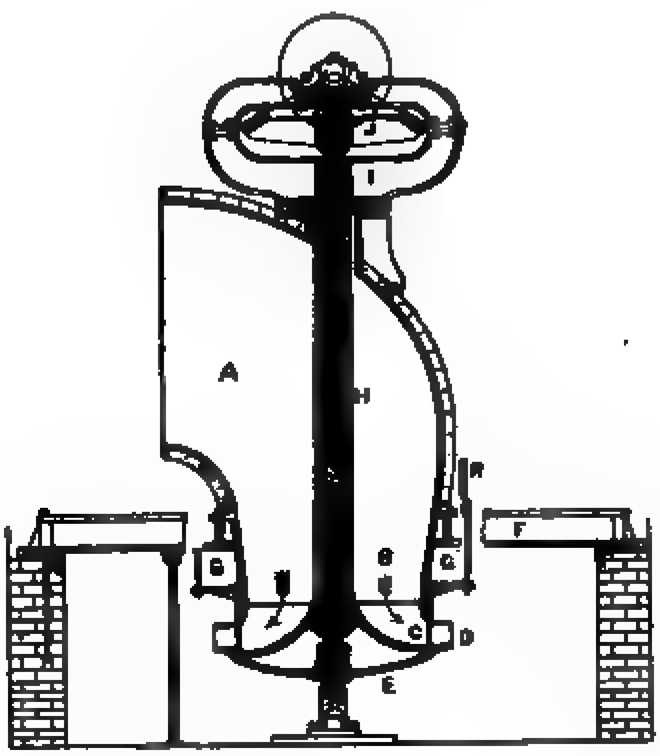

water thus remains at a constant distance from the axis. This system of construction is sometimes termed Euler's after the alleged inventor. The credit of its adaptation to practical use appears to be due to M. Fontaine of Chartres, France. The wheel is usually cased in so that it may be set at any point in the fall, utilizing the so-called suction of that part below it, as well as the pressure due to the column above it. This last arrangement constitutes the chief peculiarity of the Jonval wheel, which is essentially the same as Fontaine's.

The Bodine-Jonval Turbine, manufactured by Messrs. Rockfellow & Sleeper of Mt. Morris, N. Y., is represented in Figs. 4248, 4249, and 4250, and is one of the best modern forms of this class of wheel. Fig. 4248 shows the wheel removed from its case; Fig. 4249 shows the case and arrangement of gates; and Fig. 4250 shows a section of the wheel and guides. The wheel is cast in one piece, of iron or brass, and is held in position by a bridge-tree above and below, secured firmly to the case. By means of an adjustable step, the height of the wheel is regulated to the case so as to

4249. 4250.

prevent loss of water by leakage. The shape of the buckets is clearly shown in Fig. 4248. They are placed between two cylinders, the inner one of which is connected with the hub by a web or disk. The gate is of the register pattern, as shown in Fig. 4249, being an annular plate with flanges projecting upward at its edges, and the space betwen the flanges perforated with openings having radial sides and occupying a little less than one-half of the whole space, leaving the solid part of the ring

between the flanges of the same form as the openings. The upper edges around the openings are slightly rounded to lessen the contraction of the stream entering. The gate is opened and closed by a pinion, having a vertical shaft passing up through the top of the curb to a hand-wheel, which pinion works into a short rack bolted to the outer flange of the gate-plate. The guides are of cast iron, of the form shown in Fig. 4250, so spaced that the gate when open just covers the top of each guide, and when closed projects slightly upon each of two adjacent guides.

This wheel is claimed to run steadily and evenly, and to be free from leakage. From a report of tests made by Mr. Hiram F. Mills, C. E., at Lowell, Mass., in 1870, the mean maximum efficiency is as follows: with full gate, 75.9 per cent. of the power of the water; with three-quarters gate, 72 per cent.; with half gate, 61.3 per cent.; and with quarter gate, 51.7 per cent.

III. Inward-Flow Turbines.—These wheels are surrounded by annular cases, in which are guide-passages which direct the water inward to the wheel-buckets.

The Swain Wheel, devised and constructed by Mr. A. M. Swain of North Chelmsford, Mass., was the first of this type. Mr. Swain's invention consisted in the introduction of a double curve in the form of the inwardly discharging bucket, so that the discharge is downward instead of inward, and the long double curve of the bucket retains the water until it has received a very large percentage of its initial power. These buckets are formed of sheet metal, either iron, steel, or bronze, stamped in dies, and having projecting tenons on their edges, by means of which, when placed in a suitable mould, the connection between the bucket and the rims of the wheel, which are cast around the buckets, is made secure.

The construction of the Swain wheel is shown in Fig. 4251. Fig. 4252 is a horizontal section just below the crown-plate, and partially shows the form of the bucket. Fig 4253 is a development of a portion of the cylindrical surface of the wheel containing the outer edges of the buckets. The

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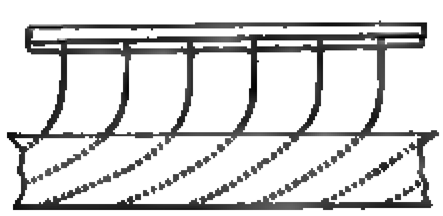

lower curb C is a strong disk of cast iron, with a short cylinder on which the gate moves, and an inner tube with diverging sides through which the water leaving the wheel is discharged into the pit. S is the step, a cylinder of white oak. It is supplied with water by pipe f, and can be reached by removing the piece a. The screws t serve to adjust the wheel vertically. The gate G is made with two cylinders N and M, attached at their tops to a disk Q, which forms an angle of 80° to the cylinders. The gate has 24 guides set to form an angle of 14°, with the tangent to the wheel passing through their inner edges. Outside of and in a line with the thick guides are placed three stands, one of which is seen at O. These support the chamber E and the wheel-cover X. The lower disk of this chamber is slotted, so that the guides may enter the chamber when the gate is raised, by means of the hoisting-rods which pass through the thick guides. Fig. 4251 represents the gate fully opened. The gate is opened by lowering, and closed by raising it, so that when the gate is first opened, the water is admitted into the wheel immediately under the crown, and the depth of the section of the stream passing through the guides is increased in proportion as the gate is opened. The lower edge of the chamber and the upper edge of the gate are finished so as to form a close joint when brought into contact. W is the wheel, having 25 buckets of bronze. According to tests of this wheel made by Mr J. B. Francis in Lowell, Mass., in 1874, its efficiency from about two-thirds gate to full gate varies from 0.828 to 0.839.

Following the Swain wheel came a great variety of wheels, containing the same features of an inward and downward discharge, but of a cheaper construction, being usually cast in one piece; but some of them have given, when tested by the Prony brake, such excellent results that we give illustrations and descriptions of several of the best. The general principle of them all consists in guides or chutes which deliver the water at right angles, or nearly so, to the lip of the bucket, and

in buckets whose area regularly diminishes to the mouth or point of discharge, and the curve of whose sides receiving the force of the water is of a somewhat cycloidal form, so as to offer a continual resistance, until the force or weight of the water is so thoroughly exhausted that it falls away from the bucket with only the velocity due to the rotation of the wheel.

4254.

The Risdon Turbine, manufactured by Messrs. T. H. Risdon & Co. of Mt. Holly, N. J., is represented in Figs. 4254 to 4257. Fig. 4254 shows the wheel proper, with a portion of the lower band removed to exhibit the form of the band and buckets. The band serves to strengthen the wheel and to make a suitably-shaped outlet for the water through the lower part of the wheel. A vertical section of the wheel is shown in Fig. 4255, and a horizontal section in Fig. 4256. The various parts are indicated by letters in Fig. 4257. At *B* are the stationary guides; *C* is the cylinder-gate; *D*, part of the gate projecting between the guides; *F*, V-shaped portions of the crown-plate resting on stationary guide; *G*, slots in pieces *F* to allow the gate to rise; *L*, spider or gate-arms; *M*, rack and pinion; *N*, gate-stand; *P*, balance cylinder or chamber, provided with water-passages to relieve it of internal pressure; *R*, lower guide-rim; *S*, draught-tube; *V*, main water-wheel shaft; and *W*, gate-shaft. The V-shaped pieces *F* are cast on the crown-plate, and, as the gate rises in their slots, the crown-plate may be placed just above the wheel and within the cylinder-gate. On the plate is attached a ring of flexible material which bears against the inside of the gate; this is kept tight by the water-pressure, and leakage is thus prevented. From the centre of the crown-plate rises a long hub, to the outside of which a spider is attached. The outer ends of the spider-arms are secured to the cylinder-gate, which is moved by means of a rack and pinion in connection with the spider, the long hub serving as a guide for the motion of the latter. On the upper end of the spider is a flat disk fitting within a small cylinder, and moving within the cylinder whenever the gate is moved; this cylinder is open at the bottom and closed at its upper end, and is fastened securely on the top of the long central hub. This moving disk has a packing-ring on its under side similar to the one on the top of the crown-plate, to prevent leak. From the upper side of this disk all pressure is removed by the passages (shown by heavy dark lines) allowing the water to escape down the central hub. The object of this device is to counterbalance the weight of the gate by upward pressure of the water on the under side of the disk. Fig. 4255 shows the position of the gate when fully raised, representing the lower edge of the gate coinciding with the upper part of the water-course through the wheel, showing the projections that are between the guides on the outside of the gate. These projections are more distinctly shown in Fig. 4257. It will be seen that the stationary guides make a gradually converging passage on two sides; the lower guide-rim inclines upward as it approaches the wheel, making the third side of the water-passage, and the under sides of the projections inclining downward as they approach the wheel make the fourth side, thus completing it of a form which the manufacturers claim offers the least resistance to the water.

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At a competitive test of water-wheels conducted at the Centennial Exhibition, the Risdon wheel obtained the highest results, as follows: per cent. at full gate or discharge, 87.66; seven-eighths gate, 86.33; three-fourths gate, 82.52; half gate, 75.35.

The American Turbine, manufactured by Messrs. Stout, Mills & Temple of Dayton, Ohio, is represented in Figs. 4258, 4259, and 4260. Fig. 4258 shows the wheel only; Fig. 4259, the case; and Fig. 4260 is a plan view of the wheel and gates. The wheels and cases are made entirely of iron, with bridge-trees above and below. There are from six to twelve graduated chutes on each wheel, depending on their diameter. Each gate and chute is cast in one piece, and moves horizontally, the

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4260.

chutes being hinged at a point near the inside of the case, or point of depletion. Thus, as the gates are opened or closed, it will be seen that the chutes move with the gates, as in Fig. 4260; the upper portion of the case is removed to show their form. The lines behind the chutes represent the guards, which are cast between the upper and lower plates of the case. These guards relieve the gates from the hydrostatic pressure of the head; consequently the gates are easily opened and closed by a ring and levers, operated with a segment and pinion. The gate-rod, on which the pinion is placed, passes up through the husk or floor, with a hand-wheel on the upper end for the purpose of operating the gates. It is claimed that, whether the gates are fully or partially opened, the chutes are always adjusted to suit the amount of water admitted through the gates, in consequence of which a high percentage is obtained with partial gates.

The following table, submitted by the manufacturers, shows results of test of this wheel made by Mr. James E. Emerson in 1873 (diameter of wheel, 48 in.; data for one minute):

Table of Tests of American Turbine.

Gate.	Head.	Percentage.	Gate.	Head.	Percentage.	Gate.	Head.	Percentage.
Whole gate..	18 18	82 84	Three-fourths.	18 41	81.49	One-half.....	18 86	69 64
Seven-eighths	18 18	82 60	Five-eighths .	18.45	75 18	One-fourth...	19.28	50.08

Alcott's Turbine, manufactured by Messrs. T. C. Alcott & Son of Mt. Holly, N. J., is represented in Figs. 4261, 4262, and 4263. Fig. 4261 represents the wheel out of the case; Fig. 4262 is a vertical section; and Fig. 4263 shows the outer case and cylinder, with the bridge-tree and wooden step which supports the wheel in position. In Fig. 4262, *A* represents the interior lines of the wheel and indicates its concave rim; *B* is that portion of the chute comprised in the outer

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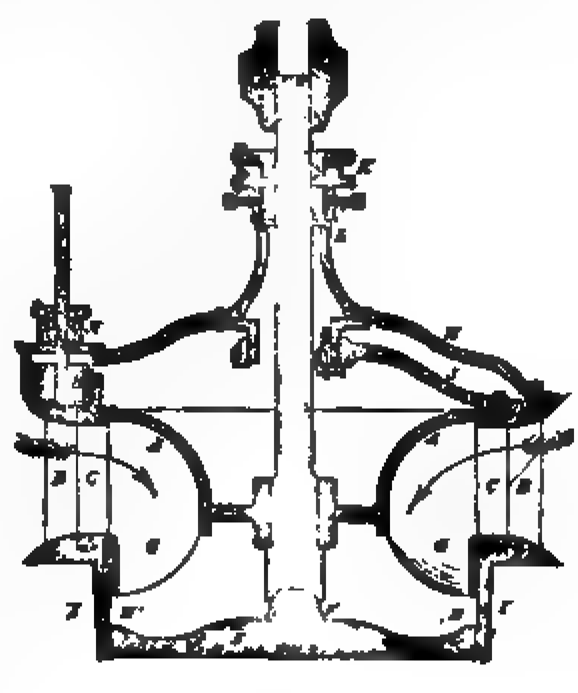

case: *C* is that portion of the chute comprised in the register-gate; *D* is the pinion which works into a segment upon the register-gate for the purpose of opening or closing the same. The arrows indicate the course of the water through the chutes or buckets of the wheel. The other parts are as follows: *E*, cross-

arms or bridge-tree; *F*, wooden step upon which the wheel revolves; *G*, bucket of the wheel; *H*, band surrounding buckets on outside; *I*, draught-tube; *J*, gate-arms, supported at the centre, serving the double purpose of keeping the gate concentric with the guides without unnecessary friction, and bearing most of the weight at the centre where the friction is least; *K*, packing-box, which prevents leakage around the shaft; *L*, dome, containing wooden followers at top; *M*, crown or cover, overlapping outer casing; and *N*, packing-box for gate-shaft, to prevent leakage. The principal advantages claimed for the wheel are as follows: stationary water-ways, by which the direction of the column of water entering the wheel is never changed or broken, or its velocity checked; an opening to each bucket of the wheel, all combined in one gate; and simplicity of construction.

4263

Burnham's Standard Turbine, manufactured by Mr. N. F. Burnham of Richmond, Va., is represented in Figs. 4264 and 4265. Fig. 4264 is a plan view, with horizontal sections on the lines *A B*, *C D*, and *F F* of Fig. 4265, showing part of the buckets of the wheel, chutes or water-ways in the curb, and ports in the gate-ring. Fig. 4265 is a vertical section of the entire wheel on the line *Y Y* of Fig. 4264, showing the upper journal-box, with shaft of wheel, stuffing-box, eccentric wheel, concave hub, and bucket, together with wood step and cross or bridge to support the step.

This turbine is the latest of a number of inventions made by its manufacturer, the series beginning with improvements on the Jonval wheel. The principles of its construction are stated as follows: 1. Extending the inside part of the buckets down to correspond with the extended wall of the hub, and curving the lower part of them up to the original length at the periphery of the wheel; 2. Forming a water-tight groove for the upper projecting rim of the gate, to prevent sand or dirt from

4264.

4265.

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being drawn into the working parts; 3. Operating the gate by an eccentric wheel instead of by cog-gearing or levers; 4. Supporting the upper bearing-box on brackets, the lower end of the latter resting on the cover, directly over the body of the case, forming an upper bearing for the wheel-shaft; 5. Placing a packing-box under the bearing, which prevents the forcing of sand into the journal-box by the water. For tests of this wheel see table at end of article. The manufacturer states that on trials at his testing flume a yield of 84 per cent. of power has been obtained.

The Leffel Double Turbine, manufactured by Messrs. James Leffel & Co. of Springfield, O., while giving an inward and downward flow, differs materially in construction from other forms of turbine. It is described by its manufacturers as follows: "There is in it a combination of two independent sets and kinds of buckets, one a vertical, the other a central discharge, each entirely different in its principle of action upon the water, yet each wheel or series of buckets receiving its water from the same set of guides at the same time; but the water is acted upon but once, since half the water admitted by the guides passes to one wheel, and the other half of the water to the other wheel; the water leaving both wheels or sets of buckets at the same time and as quickly as possible. These two sets of buckets are so combined as to make really but one wheel; that is, both are cast in one piece and placed upon the same shaft. By this arrangement there is admitted the greatest possible volume of water, consistent with its economical use, to a wheel of any given size, and at the same time the greatest area for the escape of water is secured."

Fig. 4266 represents the Leffel wheel in its casing and ready for attachment to machinery to be

driven. A section of the wheel showing its mode of construction appears in Fig. 4267. Fig. 4268 shows the method of setting the wheel. Fig. 4269 represents the Leffel wheel attached to the machinery of a mill, and also the arrangement of the wooden penstock. The wheel is here shown inclosed in Leffel's patent iron globe-casing, which consists of two hemispheres of iron bolted together. A movable cap is provided, so that the wheel can be lifted bodily out. Above the cap is a bridge-tree carrying a broad oil-bearing for the support of the wheel-shaft, to which a clutch-coupling is attached. In the cover are stuffing-boxes through which the gate-rod and water-wheel shafts pass.

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The letters on Fig. 4268 correspond to the dimensions given in the following table. Two sizes of wheel, for purposes of illustration only, are here referred to. The measurements are in inches.

Table showing Dimensions, etc., of the Leffel Wheel.

		B	C	D	E	F	G	
SIZE OF [illegible]	Diameter of of Wheel and Casing.	Internal Dimensions of Penstock.	Height of Shaft from Floor of Penstock to Centre of Coupling.	Diameter of Bore in Upper Half of Coupling.	Depth of Pit from Floor where Wheel rests to Bottom of Pit.	Diameter of Hole in the Floor of Flume for Wheel Cylinder.	Distance from Centre of Gate-rod to Centre of Wheel-Shaft.	Cross-Section or Size of Entrance for Water to Penstock.
No. 2 ..	114	107 to 185	65	6¼	62 to 82	95	52	74 by 186
" 18.	84½	52 to 60	36½	2⅝	28 to 33	37	15½	40 by 60

4268.

Setting Turbines.—The method of setting the Leffel turbine shown in Fig. 4268 will indicate the general mode of placing all wheels of this class. In Fig. 4270 is shown the arrangement of timbers used by Messrs. Leffel & Co. in the construction of a plain wooden flume. Fig 4271 represents a wheel of this type as constructed by Messrs. Poole & Hunt of Baltimore, fitted to a cast-iron penstock with cast-iron inlet-pipe. One side of a section of

the pipe is detached in order that the wheel may be exhibited. This arrangement is especially commendable.

TESTING TURBINES.—The following practical suggestions are by Mr. S. S. Webber, C. E.: "The measurement of the water flowing through the wheel is obtained by constructing a weir across the end of a tight tail-race or flume, which should be wide and deep enough to allow the water to become quiet and find a level after its rapid passage through the wheel; and in cases where the nature of the surroundings will not permit of this, a rack or strainer reaching to the bottom of the race, and fine enough to set the water back slightly, should be put in across the flume. This will even the flow beyond and break up any currents. This rack must be at least 15, and better 20 ft. back from the weir. The construction of the weir is the next step. It may be of any length, at least 8 ft., and for any wheel over 30 in. under 20 ft. head, 9 or 10 ft. is better; and the larger wheels require a weir long in proportion. It is usually made of plank, and the edge over which the water flows must be true and level, and the sides also true and at right angles to the top or crest. The up-stream edges must be sharp and smooth, and the down stream edges beveled off, so that the water will only come in contact with sharp up-stream edges; then, from the bottom of the race to the top or crest of weir, the height must be at least three times the depth of water that will flow over. A weir one foot deep should be two feet shorter than the width of tail-race, or else the full width; as in one case a deduction must be made in the calculation from the length of the weir for end contraction in the flow of water, and in the other none, as, the weir being full width, there is no end contraction.

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Also, the water below or outside should not be within a foot of the crest of weir, so that it shall not impede the flow-over. And lastly, in taking the height of water on weir, it should be measured at a point far enough back or up stream to be above the curvature of the surface occasioned by the fall in height, as the water approaches the weir with increasing velocity, and this measuring point should not be more than one-third the length of weir back. The Hook gauge for taking this measurement should be located at this point; or else, if placed below the weir, in a can or vessel, this latter must be connected by a straight pipe, that has its up-stream end opening at the point mentioned. This will insure a correct reading of the head on weir. The formula given by Mr. Francis for determining the flow in cubic feet, which is the only one based on accurate experiment, and universally used, is as follows: $Q = 3.33\,(L - 0.1\,n\,h)\,h^{\frac{3}{2}}$; where Q = number of cubic feet per second, L = length of weir in feet, h = depth of water flowing over in feet, and n = number of end contractions.

"The flume, or penstock, may be of wood or iron, securely braced, and tight in all the joints, and should have a firm, rigid foundation or platform, upon which the wheel is to be set. In setting the wheel, it should fit its case easily, so as not to bind when the weight of water is on it, and should be tight in the gate and stuffing-box, so that no leakage will take place, as no deductions should be allowed to a wheel for leaky gates, since the water leaking through becomes effective when the gates

are opened. But if there be any leakage through the flume, or at the joint of the wheel-case and floor of the penstock, this leakage, if flowing over the weir, may first be measured with the gauge and deducted from the whole when the wheel is running, as it is only the water actually acting on the wheel that should be charged to it. Having got everything tight, and the wheel to turn easily in its bearings, a friction-pulley with a smooth, accurately-turned face, and perfectly balanced, is keyed on the shaft. The diameter should be about 3 ft. by 12 in. face for small wheels, say not over 30 in., while a larger one is required for wheels of greater power. It is better to have the Prony brake made in halves, of metal lined with blocks of hard wood, and to inclose the entire pulley, except a narrow opening of a couple of inches, to allow for tightening up. The surface of the wooden blocks should be grooved or 'herring-boned,' to distribute the lubricating water, which should be rendered a little greasy by dissolving soft soap in it. By having holes in the brake leading to the grooves, the soapy water can be made to give a perfectly even, regular friction at all speeds, while oil is likely to heat and gum, and give a deal of trouble, and, even if mixed with water, it is not nearly so good as soap. Attached to the brake-casting is an arm or lever, at the further end of which is an eye-bolt with a knife-edge, to which the scale-beam of the weighing apparatus is attached. The distance from the centre of wheel-shaft or pulley to the knife-edge in the brake-lever is the radius of a circle, whose circumference is the distance in feet the weight lifted is supposed to travel at each turn of the wheel. The scale-beam is either of metal and graduated to pounds, or is provided with a weight-pan hanging from the end, the weights being in all cases multiplied by the leverage used for the total effective weight lifted. To prevent jar and vibration, a rod and piston should be attached to the opposite end of the scale-beam from the weights, which works loosely in a cylinder or dash-pot filled with water. This arrangement, allowing the lever to work easily, prevents rattling or jarring; and the weight of the rod and piston, after being put in the dash-pot, should be counterbalanced by hanging an equal weight on the weight end of the scale-beam. This completes the weighing apparatus, which, with a speed-counter fastened to the wheel-shaft, to register the times per minute, completes the whole."

Horse-Power of Turbines.—To calculate the horse-power of a turbine wheel: Multiply the cubic feet of water discharged per minute by the weight of a cubic foot of water at average temperature. Multiply this product by the height of head, and divide by 33,000. As no wheel can utilize 100 per cent. of the water, the quotient is taken as full value, and multiplied by the percentage found to be utilized by experiment in order to obtain the net horse-power.

Example.—What is the net horse-power of a wheel which discharges 3,168 cub. ft. of water per minute under 15 ft. head, utilizing 80 per cent. of full power of the water? Taking the weight of 1 cub. ft. of water at 62½ lbs., we have 3,168 × 62½ = 197,472. This multiplied by 15 gives 2,962,080, which divided by 33,000 gives 89.76 as full value of water; and 89.76 × .80 (per cent. utilized) = 71.8080 net horse-power.

Works for Reference.—"Lowell Hydraulic Experiments," Francis, Boston, 1855; "Steam-Engines and Prime Movers," Rankine, London, 1859; "Hydraulic Motors," Mahan, New York, 1873; "Hydraulics," Weisbach ("Mechanics of Engineering"), New York, 1877. See also list of works under Hydrostatics and Mechanics.

WELL-BORING. The Well-Auger.—The most expeditious means of sinking wells in clay, gravel, etc., is by the use of the well-auger, an improved form of which implement, as manufactured by the Pierce Well Excavator Company of New York, is represented in Fig. 4272. This is attached to a rod suspended from a rope which passes over a pulley at the top of a derrick, and thence is led to a wheel and axle. To the auger-rod is secured an arm or arms whereby the tool is rotated and so screwed down into the earth, by man- or horse-power. About eight turns cause the auger to become filled with soil, when it is lifted, emptied, and replaced. It is said that wells ranging in diameter from 6 to 30 in. can be bored with this implement, at the rate of from 40 to 60 ft. per day. The

auger used for boring quicksand is shaped similarly to the ordinary wood-boring tool, having a wide spiral thread. The shank is hollow, and is arranged with air-valves, so that when the auger is lifted no suction is produced. When the thread becomes loaded with sand, the tool is drawn up into an inclosing cylinder. This, in connection with leather valves near the end of the auger, holds the sand in place until the implement is removed from the well and emptied.

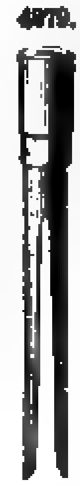
4272.

ARTESIAN WELLS.—A general description of the processes of boring, tubing, and pumpng, as practised in western Pennsylvania, may best serve to illustrate the latest advances made in the methods of sinking artesian wells. Directly over the site of the proposed well a wooden derrick or open tower is erected, 14 to 16 ft. square at the base, and 30 to 60 ft. high, the four corner-posts converging so as to form a square at the top 2½ ft. in diameter, upon which rests a heavy framework for the reception of the pulley over which the drill-rope is to play. Near the bottom of the derrick, and in range with the band-wheel from which the power is derived, is a shaft of timber 6 or 8 ft. long and about 8 in. in diameter, mounted on journals, and similar in character to the common hoisting windlass. Upon each end of this shaft is driven a large pulley called the bull-wheel; between these, upon the main shaft, the drill-rope, a cable of from 1¼ to 1¾ in. in diameter, is coiled, the outer end passing from it over the pulley on the top of the derrick, and attached to the drilling tools. When these are to be lowered or withdrawn, it is done by means of power applied to the bull-wheel. In localities where the rock is some distance below the surface, it is customary to drive down, by the aid of a suitable weight and guideway, a heavy metal pipe, called the drive-pipe; this is usually of cast iron, from 6 to 8 in. in diameter and an inch in thickness; it is driven in sections of 10 ft., and great care is needed that it be not bent or deflected, since it is to guide the drilling tools. The engine is so placed that its drive- or balance-wheel shall be from 20 to 25 ft. from the centre of the derrick, and at one-half this distance is planted the sampson-post, a heavy hewn timber from 12 to 18 in. square and 12 ft. high, the top of which is fitted to receive the working-beam. This working- or walking-beam transmits and applies the power to the drills; it is of wood, 12 or 16 in. square, and of such a length that when balanced upon the sampson-post one end may stand directly over and connect, by means of a connecting-rod, with a crank attached to the shaft of the drive-wheel; by the revolution of this crank, which has a radius of about 20 in., a reciprocating movement is given to the farther end of the working-beam; on this is bolted an iron joint, to which may be attached the temper-screw when drilling, or the sucker-rods when pumping. The drilling tools consist of centre-bits, reamers, an auger-stem, jar, and sinker-bar. The centre bit, Fig. 4273, is of 2¾-inch wrought iron, 3½ ft. long, and having a wedge-shaped cutting edge of steel, 3½ to 6 in. on the face. The reamer, Fig. 4274, which follows this and serves to enlarge and trim out the hole, is very similar in shape, though about an inch broader on the face, which is also more blunt; the average weight of each is about 75 lbs. The auger-stem, Fig. 4275, into which bits, reamers, and dislodging tools are screwed, is a wrought-iron bar about 20 ft. long. The sinker-bar, Fig. 4276, a heavy rod of iron 10 ft. long, serves to increase the force of the blow; it is separated from the auger-stem by an ingenious contrivance called a jar, Fig. 4277, consisting of two links or loops of iron or steel, which slide in upon each other when the drill strikes bottom, thus, by a quick blow upon the top of the auger-stem, increasing the effect of the fall; and on the upward movement the sudden jerk or jar serves to loosen the tools, in case they become wedged. When connected, these tools weigh from 800 to 1,600 lbs., as the hardness of the rock requires. The drill-rope is attached to the work-

4277.

4273. 4274. 4553. 4275. 4276.

4278.



ing-beam by means of a temper-screw, Fig. 4278, suspended from it and made fast to the rope by a screw-clamp. This temper-screw is about 3 ft. long, and is made with a coarse thread that works in a thin frame. At the lower end of this screw is a wheel, by which it is let down after each stroke, whereby the tension is regulated and the drill properly guided. The rope-socket, Fig. 4279, is for attaching the sinker-bar to the drill-rope. The tools are lifted and dropped by the rocking motion of the working-beam, and lowered or withdrawn by aid of the bull-wheel and shaft. The sediment and battered rock are removed by means of a sand-pump, Fig. 4280, which is a heavy metal tube, slightly smaller than the well-bore, and about 6 ft. long, with the lower end closed by a simple valve opening upward; this is lowered and withdrawn by a light rope, and the well-man by an examination of its contents is informed of the progress and prospects of his work. The pump is used after each drilling of 6 to 12 in. Fig. 4281 represents the working of the boring tools in the Pennsylvania oil region. The tubing of a well consists of a heavy iron pipe lowered in sections, the joints of which are flush both inside and out. At the lower end of the first section is a simple ball-valve pump, the piston of which is connected with the working-beam by jointed poles or metal rods. When it is desirable to exclude all water from above a given point, it is effected by binding around the tubing a leather bag of flax-seed before driving it down; the swelling of this closes the space between the main wall and the tube. The steam-engines in use in western Pennsylvania range from 6 to 20 horse-power, one of 8 horse-power being sufficient to bore a well 900 ft. deep. Artesian wells have been sunk, though very slowly, by the aid of two men and an old-fashioned spring-pole, Fig. 4282.

4281

4280

Among the accidents liable to occur in the boring of artesian wells are the breaking of the drills, or their detachment from the auger-stem, and the loss of the sand-pump or the whole boring-gear by the wearing away of the drill-rope. At times the drill enters what is known as a mud-vein—a thin stratum of mud or quicksand, which often flows in so rapidly as to inclose and bury the drilling tools. There are many ingenious contrivances for the removal of these obstructions, and the forms of several of the less complex are here shown. Fig. 4283 is designed chiefly for removing detached or broken pipe or rods. It is lowered down the well-bore until the rod passes up above the ends of the two arms, when by an upward movement the two catches, being pressed forward by springs, take hold of the rod and grasp it the more firmly the greater the resistance. Fig. 4284 is of service mainly in removing a detached drill or reamer; the shorter arm acts as a guide, while the hook at the end of the larger one passes below and takes hold of the lower edge of the drill. Figs. 4285 and 4286 are also designed for removing broken rods. In Fig. 4285 the rod passes through the metal cylinder, and is prevented from falling back by the drop-catch and spring. Fig. 4286 consists of an angular claw placed at right angles to the rod by which it is lowered; this is twisted under the shoulder of the rod, thus securing it as in a wrench. Fig. 4287 is the ordinary lazy-tongs, and is of very general service, as its construction indicates.


4283. 4284. 4285. 4286. 4287.

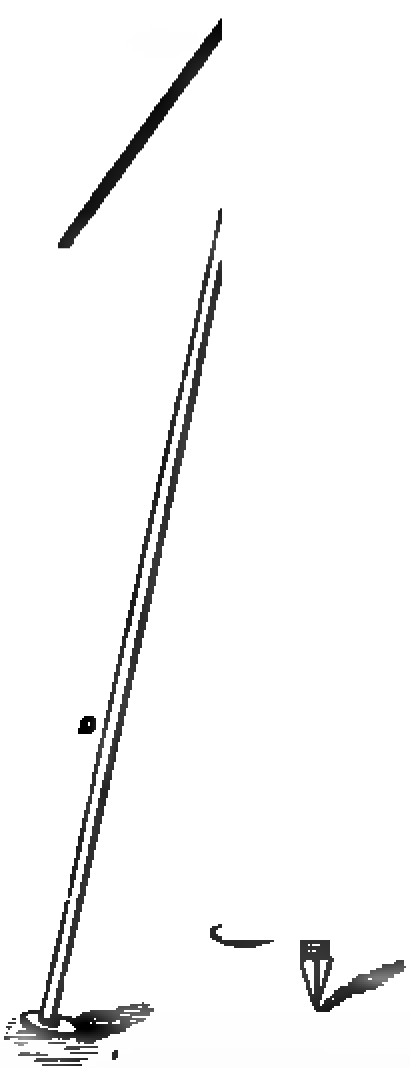
In addition to the contrivances above mentioned, the French engineers have introduced certain improved drills, pumps, etc. The drill invented by M. Goulet-Collet consists of a cylinder of sheet iron 6 ft. long, suspended by a chain, and armed at its lower end with an annular cutting-head of steel, in which two knives or chisels are inserted at right angles across the opening. These chisels serve to cut the rock, which when finely divided rises with the water through the opening; these may be provided with valves, the instrument thus serving the double purpose of drill and pump. The method of boring by means of the diamond-drill is essentially different from that described above.

When a well fails to yield a fair amount of oil or water, an increase in the flow is often effected by means of the Roberts torpedo. This is a thin water-tight cylinder of metal or paper, 4 to 6 ft. long and 2 or 3 in. in diameter, charged with powder, guncotton, or nitro-glycerine. It is lowered to the bottom of the well, or to a depth that will bring it opposite the desired stratum, and the well then flooded. The charge is exploded by a cap or electric spark, and the explosion often clears away the obstruction from the oil or water vein. Wells yielding only 5 barrels of oil per day have been increased by this means to 75 or 100 barrels.

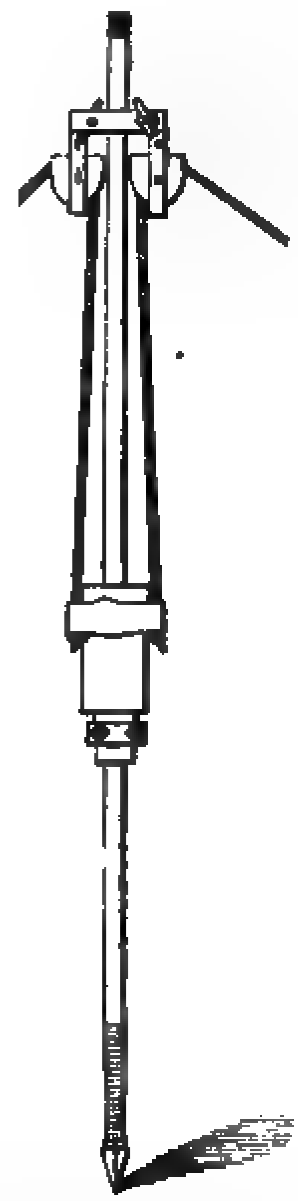
Negative artesian wells are those which serve to convey away surface waters into some absorbing stratum. They are of service about manufactories from which large quantities of impure liquids are discharged, the flow of which upon the surface would prove a nuisance. For boring of mining and other shafts, see MINE APPLIANCES.

DRIVEN WELLS.—The process of driving tube-wells resembles pile-driving, but with this distinction, that, while piles receive the blows of the monkey on their heads, the tubes are not struck at all, the blow being communicated by the clamp, which receives the blow near the ground. The tube-well, as ordinarily used, is not intended for piercing rock or solid stone formations, but it is quite capable of penetrating very hard and compact soils, and can also be successfully driven through chalk, breaking through the flints which may obstruct its passage downward. When solid masses of rock or

4288.



4289. 4290. 4291 4292



stone are reached, special means of drilling have to be provided for it. When coming upon rock or stone, the best plan is to pull up the tube and try in another spot. This applies also when deep beds of clay are driven into; for, by going a little distance off and testing again, in many cases water will be found. The mode of operation is as follows: The first or pioneer tube A, shown in Fig. 4288, is furnished with a steel point of bulbous form, and perforated with holes varying from one-eighth of an inch to one-quarter of an inch, extending from 15 in. to 3 ft. upward from the point. The enlargement of the point serves to clear a passage for the sockets by which the tubes are screwed together. On to this tube the clamp B is fastened by two bolts at about 3 ft. from the point; the clamp is of wrought iron lined with steel, and screwed internally so as to form teeth to grip the tube. Next, the cast-iron driving-weight or monkey C is slipped on to the tube above the clamp. The tube thus furnished is stood up perfectly vertical in the centre of the tripod or shear-legs D D D, in which it is retained by the latch E. The feet of the tripod should be looked to, in order that they be firmly planted, and do not slip or sink during work. The whole being now arranged in position for work, the ropes F F are made fast to the monkey and passed over the pulleys of the tripod, and driving is commenced by two men pulling the ropes and allowing the monkey

to fall on the clamp. At this point particular attention must be paid to frequently tighten both the bolts equally as the driving proceeds, for the clamp must not on any account be allowed to slip, otherwise the blow of the monkey is in a great measure lost, the result being no good to either clamp or tubes, besides wasting time. As soon as the clamp reaches the level of the earth by dint of repeated blows, the monkey should be raised, and one man, taking a turn of his rope round one of the legs of the tripod, holds the monkey suspended, while the other loosens the bolts of the clamp and raises it about 18 in., and tightens the bolts again as at the commencement. If the ground be very soft, the clamp can be raised 2 ft. or more, as it saves the frequent readjustment; if very hard, not more than 1 foot. In this manner driving is continued until the top of the tube comes below the hole in the tripod head, or top plate. Immediately it reaches this point the lengthening-bar, Fig. 4289, is brought into requisition by dropping its small end into the top of the well-tube. The object of this lengthening-bar is to keep the tube steady, and to enable the operator to have a temporary guide for the monkey to slide on, until the well-tube has been driven into the ground to within a foot of its entire length. A hollow iron plumb is lowered into the tube, so as to ascertain whether water has been reached, or whether earth of any kind has got into the tube. This indicates what depth of earth or water stands in the tube. If neither is present, the iron plumb will strike plainly on the bottom of the tube; should earth be present, by allowing the plumb to strike on it once or twice, some will adhere to the bottom, and thus indicate the nature of the soil.

When the accumulation in the well-tube is of a loose, sandy nature, if wet, it can best be withdrawn by means of the pump, which, with the reducing-socket, can be coupled on to the top of the cleaning-out tubes. When this is the case, before screwing on the pump, the funnel, Fig. 4290, should be screwed on the top of the well-tube, so that, if necessary, water can be poured down the well-tube, when, by pumping, sand and mud will be pumped up; and by continuing to pour fresh water down the tube, and pumping up through the small tubes, all the earth can be removed.

When water is struck, and stands several feet in the tube, the pump, Fig. 4291, can be applied. Fig. 4292 shows a well-tube that has been driven, and the soil disintegrated around the perforations. Fig. 4293 shows the mode of driving the tube without use of supporting standards.

The process is not by any means confined to well-sinking purposes. Iron piles can be driven most effectually, particularly where there is a great depth of water, it being quite practicable thus to drive piles 50 ft. or 100 ft. below the surface of the water. On a smaller scale the plan is also well adapted for driving telegraph-posts with rapidity for military or permanent purposes, as well as tubular posts for wire or other fencing. The uses to which the smaller sizes of tube-wells are adapted are very various; to a great extent they supply an important want of the present day in furnishing pure water for domestic use, and thus replace the old dug wells, which in most rural districts are found contiguous to cesspools, and with few exceptions are more or less contaminated by sewage. In numerous instances, by driving one of these tube-wells some 16 ft. or 20 ft. below surface springs, a pure supply can be obtained, for these tubes are found to perfectly shut off all communication from the impure water in the upper seam. To give an instance out of many hundreds, at Brandeston Hall, in Suffolk, England, the dug well which supplied the household being found to be impure, thereupon a tube was driven, and, after passing a very compact bed of clay some 20 ft. thick, chalk was met with at 36 ft., and an abundant supply of perfectly pure water obtained. The smallest-sized wells are advantageous for manufacturing purposes, for supplying moderate-sized boilers with feed-water, not only in rural districts, but in towns supplied by water-works, thus saving heavy water-rates. Many are thus in use for similar purposes, even in the very heart of London and New York, springs being found to exist in many spots where it might have been expected that deep sewers had drained away all the land-springs overlying the London clay. As it is not uncommon for a 1¼-inch tube to yield from 500 to 600 gallons per hour, constant pumping, contractors, in erecting large buildings, find them very useful both for supplying their engines and for mixing mortar, and on the completion of the contract they are taken up ready for use elsewhere. This feature of being readily transportable from place to place renders them invaluable for railway contractors, and especially so for exploring expeditions, Sir Samuel Baker and others having employed them in Africa and elsewhere for that purpose. Another use to which they are daily put is for testing ground to ascertain how deep water lies below the surface, to test the quality and quantity obtainable before sinking larger permanent tube-wells. It will readily be seen how valuable such a rapid means of obtaining such data becomes, as, before purchasing land for any purpose, the primary question of water-supply can thus be settled. (See *Engineer*, xliv., 1143.)

The depths of some of the principal artesian and other wells of the world are as follows: Sperenberg, Prussia, 4,170 ft.; Passy, France, 1,913; brine well, Kissingen, Bavaria, 2,000; Chicago, Ill., 700; County Buildings, St. Louis, Mo., 3,235; Belcher's sugar refinery, St. Louis, Mo., 2,197; Charleston, S. C., 1,250. Artesian wells in the Sahara Desert average about 200 ft.

WINDMILLS.* Windmills can be divided into two general classes according to the inclination of the shaft: 1. Horizontal mills, in which sails are so placed as to turn by the impulse of the wind in a horizontal plane, and hence about an axis exactly vertical; and, 2. Vertical mills, in which the sails turn in a nearly vertical plane, i. e., about an axis nearly horizontal.

HORIZONTAL WINDMILLS.—On account of the many disadvantages connected with the horizontal windmill, it is but seldom brought into use, being employed only in situations in which the height of the vertical sails would be objectionable, and this is liable to occur only in extraordinary cases. In this kind of mill six or more sails, consisting of plane boards, are set upright upon horizontal arms resting upon a tower and attached to a vertical axis, passing through the tower at its middle part. If the sails are fixed in position, they are set obliquely to the direction in which the wind will strike them. Outside of the whole is then placed a screen or cylindrical arrangement of boards intended

* Prepared by Alfred R. Wolff, M. E.; revised by Richard H. Buel.

to revolve, the boards being set obliquely and in planes lying in opposite courses to those of the sails. The result is, from whatever direction the wind may blow against the tower, it is always admitted by the outer boards to act on the sails most freely in that half of the side it strikes, or from which the sails are turning away, and it is partly, though by no means entirely, broken from the sails which in the other quadrant of the side are approaching the middle line.

The great objections to the horizontal windmill are: first, that only one or two sails can be effectually acted upon at the same moment; and, secondly, that the sails move in a medium of nearly the same density as that by which they are impelled, and that great resistance is offered to those sails which are approaching the middle. Hence with a like area of sails the power of the horizontal is always much less than that of the vertical mill. Smeaton estimated the former at one-tenth only of the latter; but Sir David Brewster, showing that in this he overlooked the loss in vertical mills of one component of the wind's pressure, concluded that the ratio is no less than 1 : 3 or 4.

Wind as Motive-Power.—When the density of air is uniform throughout, the atmosphere remains at rest; but, as soon as this equilibrium is destroyed, a movement results which takes the name of wind. If in one part of the atmosphere the air becomes more dense, it rushes toward that part whose density is less, in the same manner that the air compressed in a pair of bellows escapes by its orifice. These currents of air are caused directly or indirectly by differences of temperature at different times and localities, giving rise to changes of density and varying the production and condensation of watery vapor. The variations in the velocity and pressure of the wind are considerable even within a brief time, and sometimes sudden and extreme. Winds of immense velocity and pressure are on record. A very violent gale in Scotland registered by an excellent anemometer a pressure of 45 lbs. per square foot. During the severe storm at London on Feb. 6, 1867, the anemometer at Lloyd's registered a pressure of 35 lbs. to the square foot. The gauge at Girard College, Philadelphia, broke under a strain of 42 lbs. per square foot, a tornado passing at the moment within a quarter of a mile. At the Central Park Observatory, in the middle of March, 1876, a wind was recorded of 28.5 lbs. per square foot pressure.

The tables from which the pressure corresponding to a given velocity of wind is generally obtained are not trustworthy, as they do not take into account the effect of temperature. Mr. Alfred R. Wolff, M. E., was the first to compute a table in which the effect of temperature received its due consideration, and of which the following is a summary:

Table showing Velocity and Pressure of Wind.

VELOCITY OF WIND.		PRESSURE IN POUNDS PER SQUARE FOOT OF PLANE SURFACE WHEN P = 2116.5 AND TEMPERATURE OF WIND =					
Miles per Hour.	Feet per Second.	0° F.	20° F.	40° F.	60° F.	80° F.	100° F.
1	1.46⅔	.005371	.005147	.004940	.004750	.004574	.004410
2	2.93⅓	.021482	.020586	.019761	.019001	.018294	.017641
3	4.40	.048335	.046318	.044465	.042751	.041166	.039684
4	5.86⅔	.085980	.082345	.079048	.076008	.073185	.070568
5	7.33⅓	.134271	.128668	.123514	.118758	.114355	.110267
6	8.80	.193354	.185287	.177867	.171017	.164675	.158784
7	10.26⅔	.263186	.252205	.242112	.232790	.224148	.216140
8	11.73⅓	.343767	.329423	.316228	.304050	.292774	.282265
9	13.20	.435088	.416945	.400248	.384828	.370565	.357305
10	14.66⅔	.537183	.514772	.494151	.475121	.457498	.441195
11	16.13⅓	.650036	.622908	.597955	.574923	.553600	.533815
12	17.60	.773645	.741357	.711656	.684244	.658865	.635301
13	19.06⅔	.908020	.870122	.835260	.803085	.773296	.745638
14	20.53⅓	1.053166	1.010206	.968770	.931449	.896879	.864514
15	22.00	1.209067	1.158616	1.112190	1.069347	1.029670	.992641
16	23.46⅔	1.375798	1.318354	1.265528	1.216768	1.171621	1.129707
17	24.93⅓	1.553278	1.488425	1.428786	1.373721	1.322751	1.275429
18	26.40	1.741556	1.668[illegible]89	1.601951	1.540180	1.483066	1.429470
19	27.86⅔	1.940684	1.859596	1.785056	1.716260	1.652571	1.593489
20	29.33⅓	2.150516	2.060705	1.978095	1.901853	1.831270	1.765740
25	36.66⅔	3.362250	3.221749	3.092521	2.973261	2.862757	2.760859
30	44.00	4.845284	4.642662	4.456811	4.284844	4.125157	3.97[illegible]871
35	51.33⅓	6.600829	6.324565	6.070498	5.836055	5.619016	5.417590
40	58.66⅔	8.630351	8.268791	7.936807	7.627948	7.345581	7.082012
45	66.00	10.935822	10.476877	10.05[illegible]175	9.666070	9.305975	9.971746
50	73.33⅓	13.518265	12.950585	12.428668	11.947178	11.501614	11.088[illegible]85
60	88.00	19.525804	18.702998	17.947145	17.250417	16.605025	16.006[illegible]91
80	117.33⅓	34.981580	33.497800	32.13992	30.877[illegible]5	29.715[illegible]2	28.808716

In making these computations attention was paid to the facts that the pressure depends upon both the velocity and the density of the air, and that this density depends upon the temperature, the barometric pressure, and the pressure due to the motion of the air. This table is for the average height of barometer, and for any other barometric pressure the figures in the table must simply be multiplied by the ratio of this barometric pressure reduced to its value for temperature of air (32° F.) to 2116.5. Thus, letting p_s = barometric pressure at any absolute temperature t, then $p = \frac{p_s \times t}{491.4}$, and the table must be multiplied by $\frac{p}{2116.5}$.

Examples.—1. Let the velocity of wind = 15 miles per hour, the barometric pressure = 14.9 lbs per square inch (2145.6 lbs. per square foot), and temperature of wind = 80° F. Then $p = \frac{p_s \times t}{491.4} =$

$\frac{2145.6 \times (459.4 + 80)}{491.4} = 2355.2$. From the table we find the pressure of wind corresponding to a velocity of 15 miles per hour, and at a temperature of 80° F., to be equal to 1.029670. This quantity must be multiplied by $\frac{p}{2116.5} = \frac{2355.2}{2116.5}$. Therefore the pressure of wind corresponding to a velocity of 15 miles per hour, barometric pressure 14.9 lbs. per square inch, and temperature 80° F., equals $\frac{1.029670 \times 2355.2}{2116.5} = 1.145797$ lb. per square foot of plane surface.

2. Let the velocity of wind = 20 miles per hour, the barometric pressure = 14.2 lbs. per square inch (2044.8 lbs. per square foot), and temperature of the wind = 40° F. Then $p = \frac{p_s \times t}{491.4} = \frac{2044.8 \times (459.4 + 40)}{491.4} = 2078.1$. From the table we find the pressure of wind corresponding to a velocity of 20 miles per hour, and at a temperature of 40° F., to be equal to 1.978095. Therefore the pressure of wind corresponding to a velocity of 20 miles per hour, barometric pressure 14.2 lbs. per square inch, and temperature 40° F., equals $\frac{1.978095 \times 2078.1}{2116.5} = 1.422480$ lb. per square foot of plane surface.

European Windmills.—The building of a vertical windmill is an ordinary tower of wood or stone, the latter commonly in the form of a frustum of a cone. The principal parts of the mill are: 1. An axle in the top of the building, inclined (as observation has shown that the impulse of the wind is very commonly exerted in lines descending at such angles) to the horizontal at angles from 10° to 15°, and on which are the sails; 2. The sails, consisting of frames with canvas stretched upon them, which, if four in number, are fixed in positions at right angles to each other, and are generally 30 to 40, and sometimes 50 ft. in length; 3. A large toothed wheel upon the horizontal axle, the teeth of which engage with those of a pinion upon—4. A vertical shaft, from which motion is imparted to the machinery.

Several methods are in use for bringing the axis of the windmill in the line of the wind, so that the sails may receive the most direct impulse from whatever point of the compass it may come. The early mills were immovable, and could only work when the wind was in one quarter. The first improvement was made by setting them on a float which could be turned around so as to catch every wind. German or post mills were formerly employed when the mill was of timber and of small size. The tower was fixed upon a strong column entering its base, which was sufficiently elevated to allow the turning of the tower as desired, by means of a long and stout lever projecting from it below, and pushed by a person on the ground. On account of the manual labor required, and the superiority and automatic action of the Dutch mill, the former kind has now gone out of service in Europe. In Dutch mills the dome only is turned, carrying the axle and sails with it into the required position, while the vertical toothed wheel merely travels about the pinion, and the connection is not broken. In order to allow the dome to turn, and at the same time to secure it in position, it is most usual to construct the tower open at the top, this opening being strengthened by a wooden rim running completely around it; and on the upper surface thus exposed is a groove in which small circular metallic casters or rollers are placed to turn on horizontal axes. The dome is made with a corresponding groove on its under side, so as to rest upon the rollers and turn on them; while it has also a flange projecting downward, surrounding the rim of the tower, small vertical rollers being here also usually fixed between the two. Thus the dome can be turned with a slight effort into any required position, and by appropriate means can be fixed if desired. The turning of the dome was formerly done by the employment of a toothed wheel, engaging in a rack on its inner side, and turned by means of an endless cord; but at the present time either of the following methods is employed.

Methods of Regulation of the Wheel.—Cubitt's method consists of a set of small vanes placed in an upright position, upon a long arm or frame projecting in the same line with the horizontal axis, but on the opposite side of the dome, the vanes nearly in the direction of the axis at right angles to the plane of the sails. By their revolution, the vanes turn a shaft and pinion, and finally act upon teeth surrounding the exterior of the dome, moving it until the wind no longer strikes the set of vanes, when the sails will be exactly in their best position to receive the impulse of the wind. A method much more simple and just as effective is found in the use of a large, strong, and flexible vane or "rudder," projecting opposite the axis and sails, the plane of the rudder being vertical, so that the wind, however shifting, acts directly upon this to bring the sails into the required position. The variations in the intensity of the wind being considerable, often so within a brief time, and sudden and extreme, it becomes necessary to have means provided for regulation, as the motion of the machinery must be uniform to perform a constant quantity of work. One method formerly employed was the use of a friction-strap applied to the outside of the wheel on the horizontal shaft; but this has entirely given way to the means of regulation by change of extent of surface offered to the wind, by increase or decrease of the amount of cloth of the sail. The latter was formerly effected by having a rope attached to each sail, or having the canvas made in three portions, controlled by separate ropes; and much trouble and delay were occasioned, as the mill required to be stopped, and a man had to ascend the sails separately to take in or let out canvas. In 1780 Mr. Andrew Meikle devised, for reefing the sails when the mill was in motion, a most ingenious application of the cen-

trifugal governor, namely, a sliding piece which operated upon rollers placed tranversely with the arms, and wound up or reefed the canvas sails when the sails attained too great a velocity; and the unfurling of the sails or increasing their speed was accomplished by a weight, which actuated a rod passing through the centre of the main axle, operated centrifugally on the sliding frames, and then unwound the canvas when the motion of the sails was too much retarded. This automatic reefing apparatus imparted to the windmill a precision of motion little inferior to some of our modern steam-engines; and by varying the weights for unfolding the sail, the power of the mill could be increased or diminished with facility. In the early part of the present century Sir William Cubitt devised a mode of reefing the sails of windmills by introducing movable shutters on the sails of the mill, which shutters are closed by a governor, like that of a steam-engine, operating upon a rod passing through the centre of the main axle. These shutters are suspended on pivots fixed about one-third of their breadth from one side, and when the wind is blowing too strong it opens the shutters and allows a portion of the wind to pass through them, and so checks the velocity of the mill.

4604.

American Windmills differ from those of European construction essentially in the form of wheel receiving the impulse of the wind. There are two methods in operation to regulate the extent of surface offered to the wind, viz., that of the centrifugal governor, and that of a "side vane," which is nearly in the plane of and directly behind the wheel, and attached to the bearing of the shaft.

The latter, the more recent method, has given great satisfaction, while the former answers well when care is taken in the design that the momentum of the moving parts is properly counterbalanced.

CONSTRUCTION OF WINDMILLS.—*Centrifugal-Governor Mills.*—The construction of a Corcoran mill, having a solid wind-wheel 12 ft. in diameter and side-vane regulation, is represented in Fig. 4294. The parts are as follows: wind-wheel, *I J K*; side-vane, *N*; flexible rudder, *M*; weighted lever, 26; connecting link, 10; slide, 24—all concentrated in iron frame 1. 17 is the supporting piece, faced on top and bored out to receive the frame 1, having a flange on top to hold lubricating compound, and being secured to the mast by four bolts. A flange also extends half way over the top of the mast. At 18 is an additional support bored out to fit 1, and secured to the post by two bolts. The main frame of the mill consists of a piece of hydraulic tubing, with a bearing to support the wind-wheel shaft resting on an anti-friction washer; it is held in place by a cap, 16. The object of this tubing coming down the mast as far as the windmill arm *I* is to give the main frame of the windmill equal leverage, with the strain brought upon the arm, and thereby

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of the central hub *D*, to which are affixed the radial arms *E E E*. Upon these are hung by boxes and adjustable gudgeons the fan sections *F F*. The section-bars are also shown in the margin, turned so as to exhibit the angle at which the slats are placed.

The operation of the mill is easily seen. As the wind strikes the sections, the angles at which the slats are placed allow the wind to pass them after first imparting a rotary motion to the wheel. Should the wind be so strong as to give too high a velocity to the wheel, the governing balls *G G*, acting through the rods *R R* and levers *B B*, will turn the sections upon their axes *F F*, so as to present a less surface to the wind; but as soon as the motion decreases, the counterweight *W* will draw the sections again into position to receive the wind. The speed of the mill is thus regulated, as is seen, by the reciprocal action of the governing and counterbalancing weights. The latter can be adjusted so as to vary the speed of the mill to some extent. The motion thus given to the self-regulating wind-wheel is communicated to other machinery through the horizontal shaft *K*, one end of which is sustained between friction-rollers and the other in a babbitt-metal bearing. If the motion

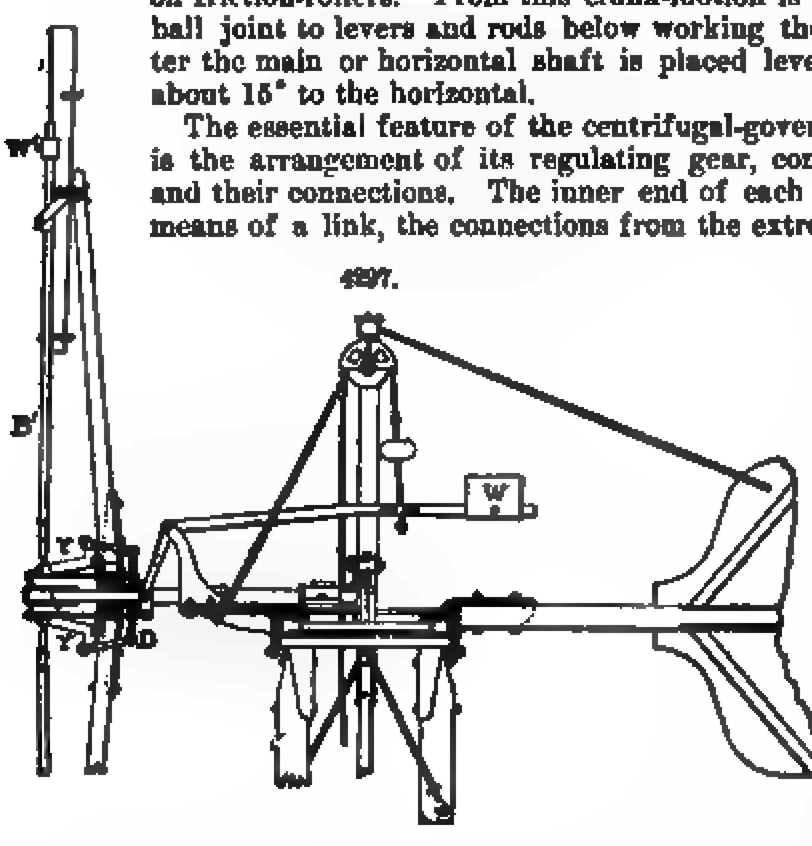
desired to be conveyed is rotary, it is transmitted through gearing as represented in Fig. 4295. But if, as is most usual with windmills, it is desired to give reciprocating motion for pumping, a crank is

4296.

fixed to the end of the shaft. The crank-pin when on its upper and lower centre must be in a line perpendicular to the centre of the turn-table and the support-casting, upon which the mill is carried on friction-rollers. From this crank-motion is conveyed by a pitman with a universal or ball joint to levers and rods below working the pump. On all mills below 30 ft. diameter the main or horizontal shaft is placed level; in larger mills the shaft is inclined at about 15° to the horizontal.

The essential feature of the centrifugal-governor type of mill represented in Fig. 4297 is the arrangement of its regulating gear, consisting of the sliding head D, elbows Y, and their connections. The inner end of each elbow is connected to the sliding head by means of a link, the connections from the extremities to the sails being made by means of "regulation" rods B', on the outer ends of which are secured the governing balls W'.

4297.



Vane-Governor Mill.—The Kewanee mill, represented in Fig. 4298, is one of the best forms of the solid-wheel mill using a vane-governor. The wheel, the slats of which are placed at equal distances apart, communicates motion to a crank. The crank-shaft has a bearing on each side of the point at which the working strain is applied. The plunger-rod works direct from the connection of the yoke around the crank, and is always in the same position, no swivel being required. The governing vane is held normally in a perpendicular position by its own weight. The effect of wind-pressure is to raise it to a horizontal position, as shown in Fig. 4298. When so placed the vane, by means of the connecting-rod B, turns the wheel edgewise to the wind. The

adjustable weight C on the vane-arm allows of the resistance of the vane being nicely regulated, so that the vane will not become horizontal until the wind attains a force likely to injure the wheel. The wheel can be turned edgewise to the wind by hand through the rod A, which is suitably connected with it. To this rod a chain is attached, which after passing over a pulley leads down to a lever near the ground.

EXPERIMENTS ON WINDMILLS.—The most trustworthy experiments to determine the best shape of sail for a given area of surface are those made by Mr. John Smeaton. These have led to the establishment of nine conclusions termed "Smeaton's maxims," and the determination of angles commonly known as the best angles of "weather." Smeaton says: "I have found, by several trials in large, the following angles to answer as well as any. The radius is supposed to be divided into six parts,

[illegible]

and one-sixth reckoning from the centre is called 1, the extremity being denoted 6. No. 1, 2, 3, 4, 5, 6 angles with the axis 72°, 71°, 72°, 74°, 77½°, 83° angle with the plane of motion (angle of weather); 18°, 19°, 18° middle, 16°, 12½°, 7° extremity." These angles are those quoted in text-books and engineering pocket-books, as the *best* angles of impulse and weather as determined by Smeaton; but it must be expressly understood that Smeaton does not term them the *best* angles of impulse, but simply says they are as good as any (probably any that were in existence at the time); and even this statement is too general, and must be taken with due allowance. Mathematical considerations show conclusively that the angle of impulse depends on the relative velocity of each point of the sail and the wind, the angle growing larger as $\frac{v}{c}$ becomes greater. It will be noticed that Smeaton's angles do not fulfill this condition, the angle of impulse at No. 2 being less than at No. 1, while the velocity is twice as great.

Coulomb's experiments consisted in the accurate determination of the work actually performed by a windmill of given dimensions with a certain velocity of wind, and would serve as an excellent standard to test the results obtained by calculations based on theory, had proper care been taken to determine the velocity of the wind at the same time that the mechanical effect was being measured. Since, however, the method by which the velocity of wind was determined could not exclude a slight error, and the velocity of wind obtained may have differed somewhat from that with which the wind struck the mill, no anemometer being employed, the experiments unfortunately lose the great value which they would have otherwise possessed.

Mr. Wolff has developed the theory involved in the construction of windmills, in a series of papers published in the *Engineering and Mining Journal*, September and October, 1876. The diagram, Fig. 4299, showing the best "angles of weather" and "impulse," is a graphic representation of the conclusions reached by him. In this figure, the ordinates represent the best angles of weather and impulse expressed in degrees, the abscissas, and the ratio of the velocity of the wind to the velocity of the windmill sails. Thus, assuming the velocity of the wind to be 31.416 ft. per second, the diameter of the wheel to be 35 ft., and the number of revolutions per minute to be made to equal 30, the velocity of the wind-wheel at a point 2½ ft. from the centre of the shaft will be 7.854 ft. per second; at 5 ft. from the centre, 15.708; at 7½ ft., 23.562, etc.; and the ratio of the velocity of the wind to the velocity of the sail $\frac{v}{c}$ will at 2½ ft. from centre of shaft equal 25; at 5 ft., .50; at 7½ ft., .75, etc. The best angle of weather, i. e., the angle which the sail makes with the plane of motion of the wheel, equals therefore, at a distance 2½ ft. from the centre of the shaft, 37° 59′; at 5 ft. from the centre, 31° 43′; at 7½ ft., 26° 34′, etc.; and the best angle of impulse, i. e., the angle with which the wind strikes the sail, equals at a distance of 2½ ft. from the centre of the shaft 52° 1′; at 5 ft. from the centre, 58° 17′; at 7½ ft., 63° 26′, etc.

WIRE, MANUFACTURE OF. The first operation in wire-making is that of rolling a rod from the solid bar, which is usually from 1¼ to 1¾ in. square. The bars, if of iron, are heated in a furnace to a welding heat; if of steel, they are brought to a bright cherry-red, and are then passed through the rolls a number of times, the size at each rolling becoming reduced and the length increased, until the dimensions are suitable for the size of wire to be produced. Each rod, or rather coil, in turn is then brought to a forge, where one end is heated and hammered to a point by hand. If the wire to be made is to be of fine gauge, necessitating several drawings, the metal is softened by annealing in a suitable furnace, after which it is cleaned. The cleansing process consists in dipping the coils in vats containing dilute sulphuric acid until the surface is sufficiently attacked. The further action of the acid is arrested by dashing a mixture of lime and water over the coils as they lie upon the ground. After drying in a large oven, the wire is ready for the drawing process.

The draw-plate is simply a piece of very hard steel, which is firmly affixed to the table or bench. From the flat side of this plate (at which they have their larger extremity) to the opposite side (which is not necessarily a truly flat surface) several conical holes are pierced, their smaller orifices being carefully finished to the sizes they are respectively intended to give to the wire drawn through them. The holes in each plate are made successively smaller by minute gradations, so that the reduction of the wire and the effort required shall be, at the successive drawings, as nearly uniform as possible. The draw-plate is usually about 10 in. long and 1½ in. thick, and it is made with great care. In France it is formed by repeatedly fusing and hammering, to insure their complete union, the two lateral parts of a compound bar, one part being of wrought iron and the other of a sort of steel called *potin*, previously obtained by melting to a paste fragments of cast-iron pots with white-wood charcoal, throwing this into cold water, and repeating the melting and sudden cooling ten or twelve times. When the union of the two parts is complete, the plate is reheated and extended; and it is then several times heated and punched with successively smaller punches to secure tapering holes; though these, which are of course smallest at the steel or hardest side, are left to be finished in the cold plate by the wire-drawer himself. For extremely fine wire, the draw-plates are sometimes made of the hardest precious stones. With a plate having a hole pierced through a ruby of 0.0033 in. diameter, a silver wire 170 miles long has been drawn so nearly uniform that neither the micrometer nor the weighing of equal lengths at the two ends showed any difference in size. Generally, however, for steel-wire draw-plates, a very hard steel, known as savage or wild steel, and made out of pig metal, is employed.

Wire-Drawing.—The workmen stand before a bench on which are a number of cylinders. These are heavily built, and are rotated by vertical shafts which extend under the bench. Just below each drum is a cam which acts upon the pivoted lever. To the end of this lever is fastened a chain which is attached to nippers or to a dog. Having thrown his coil over a reel, the workman inserts

the pointed end as far as possible through the proper hole in the draw-plate. Then, with the dog, he grasps the extremity which protrudes through, watching his chance to do so as the cam in turning allows the nippers to be moved to the right. As soon as a firm hold of the wire is obtained, the cam in its revolution acts upon the lever with great power, and thus the wire is dragged through the plate for several inches. The nippers are loosed, and a fresh grasp is obtained close to the plate; and this is repeated until a sufficient length of wire is made to allow the end to be carried to the cylinder and there secured in the vise provided for the purpose. The cylinder, meanwhile, is out of action; but as soon as the wire is fastened to it, the workman presses a treadle, a clutch connects the cylinder and shaft, and the latter slowly rotates, thus drawing the wire continuously through the plate. Should the wire break, the machine is stopped, the end repointed, and the operation already described begun again. This continues until the rough rod is all drawn down to a neat cylindrical wire, which, however, is yet considerably too large in diameter. To reduce it, a second drawing through smaller holes is required; and if the wire is to be very fine, sometimes as many as 24 drawings are had, annealing in such case taking place between each drawing.

Instead of the apparatus described, wire is sometimes drawn on the old-fashioned draw-bench, for which see COINING MACHINERY. The immense quantities of steel wire used for the East River Bridge (see BRIDGES) were made in the manner above detailed.

Galvanizing Wire.—Galvanizing (or more properly zinking) wire is done as follows—the description relating to the wire used in the construction of the East River Bridge, between New York and Brooklyn: The wire is led over rollers into a bath of dilute muriatic acid heavily charged with zinc. The acid bites a clean surface, and it is supposed that some zinc is precipitated on the wire, which better insures the deposition of the melted zinc, through a large bath of which the wire is subsequently led. The zinc covering of course protects the wire from oxidation and effects of the weather. The wire is next led to large reels, whereon it is made into coils, each containing 840 ft., weighing 60 lbs. and measuring some 4 ft. 6 in. in diameter. All the wire is required to be straight wire; that is to say, when a ring is unrolled upon the floor, the wire behind must lie perfectly straight and neutral, without any tendency to spring back in the coiled form. In order to produce this straight wire, the patented process of Col. W H. Paine, assistant engineer of the bridge, is used. The wire is led from a point within the galvanizing trough in a straight line, under considerable tension, to a guide-sheave or winding-drum, located at such a distance as to permit the wire to be cooled and set before it is coiled thereon. The size of the drum is such as to cause no permanent bending of the wire.

Utilizing Waste.—There is an interesting process in the way of utilizing waste connected with this wire manufacture, which may well be noted here. Of course, in cleaning large quantities of wire, very large amounts of sulphuric acid are needed, and the vats need constant replenishment, as the acid becomes charged with impurities. There is, besides, in a factory of this kind, a great deal of waste metal and scrap of all sorts. In order to utilize both varieties of refuse, the acid is turned into a huge vat and there boiled by steam down to a proper density. Into it the scrap metal is thrown, and the whole is heated together. Then the green resulting liquid is run off into tanks and allowed to cool. The acid and iron both disappear; but instead, on pieces of wood suspended for the purpose in the cooling tanks, appears a copious deposit of sulphate of iron (copperas), a substance of commercial value.

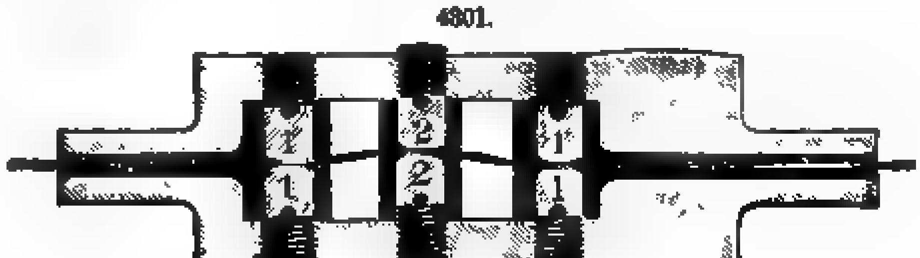
For sizes of wire, see GAUGE, WIRE; for strength of wire, WIRE ROPE. See also WIRE-FORMING MACHINERY.

WIRE-FORMING MACHINERY. Apparatus for straightening, cutting, or bending wire into various forms.

4300.

Roll Wire-Straightener.—Fig. 4300 is an apparatus for straightening wire by rolls, which are adjusted by means of thumb-screws to bear heavily on the bends of the wire as the same is pulled through. The device is designed for attachment to another machine.

4301.



Rotary Wire-Straightener.—Fig. 4301 is a sectional view of another device for straightening wire, taking the same directly from the coil or bundle. The engraving shows the method of adjusting the

dies. Those at the ends (1) are set with their wire grooves central with the holes where the wire enters and leaves, and the central die (2) a little out of line. The machine, being properly adjusted, is made to revolve at a speed of 3,000 or more revolutions per minute, according to the size of the wire, which is then passed through; the jerking motion produced by the central die being set out of line has the effect of straightening out curves and crooks in the wire.

Automatic Wire-Straightening and -Cutting Machine.—Fig. 4302 represents a machine for straightening and cutting wire, so made that the outer end of the wire is prevented from sagging or bending before the piece is divided. The wire enters through a rotary straightener, passes through feed-rolls, and is impelled by them through the bushing die and against a gauge or stop on the cut-off lever. The part serving as a fulcrum-pin for this lever extends in the form of a shaft to about the length that the machine is intended to cut. The guide-bar above and forward of this shaft is also connected with the cut-off lever, and has a groove of about the size of the wire to be cut along its entire length. An adjustable gauge at its outer end is connected by a wire with a clutch on the cam-shaft; this shaft does not revolve until the wire, passing through the straightener feed-rolls and bushing die into and through the groove in the guide-bar, strikes the gauge and pushes it out a little, thereby pulling the wire and throwing in the clutch, when the motion of the constantly rotating balance-wheel is communicated to the cam-shaft, and the cut-off lever is made to work. The simultaneous motion of the long shaft or fulcrum-pin, by means of the small levers and springs above the guide-bar, throws a cover off the groove, and the wire that is cut off drops into the forked receptacles below. These are mounted on a longitudinal piece of wrought tubing fastened in the body of the machine, and those nearest the ends have upward extensions of the rear prong, affording bearings for the long shaft and supports for the device for uncovering the groove. The handle on the small shaft above the guide-bar is for use in case the last end of any coil of wire should not be long enough to reach the gauge, in which case it will remain in the guide-bar, and a depression of the handle will cause the cover to be lifted off the groove, when the piece can be taken out. Wire can be cut on this style of machine very rapidly, one intended for cutting three-eighths and smaller wire in lengths of 16 ft. or less having cut six such lengths per minute while running at a moderate speed.

Automatic Machine for Straightening, Cutting, and Milling Wire.—Fig. 4303 represents a machine for cutting wire in short lengths, and preparing one or both ends for use as butt-pins, bolt-

4303.

shanks, and similar articles. The wire enters through the roll straightener, and is carried forward by the gripper-feed to the cutter-head, when a cam in the middle of the main shaft raises a cutting tool just sufficiently to hold it in place while the milling tool produces a point or shoulder, according to its design, when the continued action of the middle cam raises the cutting tool still farther and cuts the piece off. At the same time the newly cut end is pressed against a die above, bending, flat-

tening, squaring, or nicking it, according to the shape of the tools. The slide carrying the milling device is moved by a third cam on the long shaft, the tool receiving motion by means of a small pulley; and as soon as the operation above described is complete, the milling attachment slides back, the cutting tool returns to its previous position, and the feeding carriage retires to bring up a fresh supply of wire. This machine cuts wire of three-eighths of an inch or less diameter in lengths of 8 in. or shorter, and finishes the ends as described above at the rate of 30 per minute.

4304

Automatic Wire-forming Machines.—Fig. 4304 represents a machine that straightens wire, cuts it in suitable lengths, and forms it in various shapes, such as common rings, buckle frames and tongues, hog-rings, etc., according to the nature of the forming tools or dies used. The machine may have three or more forming motions, operated by cams set on shafts whose bearings are fastened on the sides of the bed of the machine, and motion is communicated from the one carrying the driving-pulley to the others by bevel-gears at the corners. Articles like those mentioned above are turned out at one operation at the rate of 125 and upward per minute.

Fig. 4305 represents another and simpler form of this machine, adapted only for the production of such articles as shear-point and pointless staples, coffin-handle wires, some kinds of fence-barbs, etc. The wire is straightened and carried by feed-rolls through a tube into the place where it is to be formed. Here a gauge regulates the length, and a slide carrying a forming tool with cutter attached, the whole operated by a cam on the shaft of the driving-pulley, comes forward and cuts off the wire, and forms it in shape according to the nature of the tool, pressing it against a suitable die. A cam on the end of the driving-wheel shaft, operating on a lever beneath, produces a varying pressure on the feed-rolls, causing an intermittent feed, which stops when the wire is fed out to the gauge, and begins again as soon as the wire is cut off and formed. Articles such as those mentioned above are turned out at the rate of 200 or even more per minute.

4305.

4306.

Cold-Roll Pointing Machine.—Fig. 4306 represents a machine for producing round, square, fleam,

or chisel points on rivets, wagon, hinge, and picture nails, staples, etc., by passing them between a pair of dies, the matrix of each being so shaped as to form one side of the kind of point wanted, and the dies set each in one of a pair of rolls, which are geared so that at each revolution the dies are brought together. The work can be supplied to the machine by hand, or by a semi-automatic feed. The operator places the nails or other articles one by one in the blank-holder, which carries them to the dies. This kind of work has been commonly done by blacksmiths, who heat the articles to a welding heat, and the operation is slow at best. The peculiarity of this rolling process is that a perfect point is produced by drawing the metal down without heat, which cannot generally be done by the hammer without splitting the metal.

Automatic Shear-Point Staple Machine.—Fig. 4307 represents a machine which cuts wire not exceeding three-sixteenths of an inch in size in pieces of suitable length, forms "shear" or "tack" points on them, and bends them into staples, at the rate of some 500 per minute. The wire enters from the left, between a pair of feed-rolls which are driven by the small pulley in front, and are adjusted for different sizes by the hand-wheel at the top. A cam on the shaft that carries the driving-wheel operates a cutter, and an enlargement of the same shaft carries a forming tool or "bender." Two staples are made at each revolution of the balance-wheel. Different sizes of wire and lengths of staples are provided for by slight changes in the make-up and adjustment of the tools.

4307.

4308.

Automatic Barbed-Staple Machine.—Fig. 4308 represents a machine designed for making barbed staples. The wire is cut to a suitable length, and bent in shape over a former at one motion, by tools carried by the upright slide, which is moved by a lever connected with the large cam on the left, in front. As soon as this is done, the slide carrying the barbing tool, operated by the large cam on the right in front, forces the staple against a corresponding die in the rear, producing barbs on both sides of both prongs at once; and the elbow-lever at the left of the machine, operated by the small cam at the end of the shaft that carries the balance-wheel, drives a small plunger inward from the rear and pushes the completed staple off its former, when it drops below. These staples are produced by this machine at the rate of 250 or more per minute.

We are indebted for the engravings and descriptions in this article to the manufacturer and inventor of the machines, Mr. John Adt of New Haven, Conn.

WIRE ROPE. There are two kinds of wire rope commonly manufactured. Ropes with 19 wires to the strand are more pliable, and are generally used as hoisting and running ropes. Those with 12 or 7 wires to the strand are stiffer, and are best adapted for guys, standing ropes, and rigging. Wire ropes are made with 6 strands, with a centre of hemp or wire, the former being more pliable, and wearing better over small pulleys and drums. Wire rope is as pliable as new hemp rope of the same strength; and the greater the diameter of the sheaves, pulleys, and drums, the longer the rope will last. For safe working load, allow one-fifth to one-seventh of ultimate strength, according to speed and vibration. It is better to increase the load, as speed increases the wear. Steel ropes are to some extent being substituted for iron, especially where lightness combined with strength is required; but the object in using steel in place of iron is to decrease the wear rather than reduce the size of the rope. Steel ropes are 50 per cent. stronger than iron. Numerous machines have been devised for wire-rope making; but in this country most leading manufacturers have special apparatus which they carefully keep secret.

Varieties of Wire Rope.—The following table contains a list of the varieties of wire rope made, and the purposes they are usually applied to:

Table showing Varieties and Uses of Wire Rope.

No.	No. of Strands.	No. of Wires to Strand.	Centre.	Total No. of Wires.	PURPOSE USED FOR.
1.........	6	7	Hemp.	42	Hoisting, transmission, and rigging.
2.........	7	7	Wire.	49	Standing rope and bridge cables.
3.........	6	6	Hemp.	36	Hoisting and transmission.
4.........	6	12	Hemp.	72	Hoisting, transmission, and rigging.
5.........	6	19	Hemp.	114	Hoisting.
6.........	7	19	Wire.	119	Hoisting.
7.........	6	42	Hemp.	252	Hoisting and steering.
8.........	6	49	Hemp.	294	Hoisting and steering.

Rope Nos. 7 and 8 is made by using rope Nos. 1 and 2 as strands, and twisting six of these around a hemp centre, making a rope very strong and pliant. The hemp centre is provided both for the greater degree of pliability it imparts to the rope, and because of the lessened wear upon the wire by abrasion in passing around a drum or sheave, the centre forming an elastic cushion between the strands. Rope of 19 wires to the strand is more pliable than rope of 7 wires to the strand, and hence better suited to hoisting where small drums are required; they are made both with solid and with hemp centres. Nos. 3 and 4 are seldom made. Wire rope is manufactured so as to be of indefinite length without splicing of strands, as commonly practised, the only joints being those of single wires at different points, and the joint being so made as to be stronger than the wire itself.

Flat wire rope is also made in limited quantities for hoisting purposes in mines. The various sizes, in comparison with flat hemp rope, are as follows:

Table showing Flat Ropes of Equal Strength.

STEEL WIRE.		CHARCOAL IRON WIRE.		HEMP.		Working Strain.
Size.	Weight per Foot.	Size.	Weight per Foot.	Size.	Weight per Foot.	
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Tons.
....	....	2¼-½	1.9	4 -1¼	3.3	3.3
....	....	2½-½	2.2	5 -1½	4.0	3.8
....	....	2¾-½	2.5	5½-1¾	4.3	4.5
2 -⅜	1.7	3 -½	2.7	5¾-¾	4.7	4.7
2¼-⅜	1.9	3¼-½	3.0	6 -½	5.0	5.3
....	...	3½-½	3.3	7 -1¾	6.0	6.0
2½-⅜	2.3	3¾-½	3.7	8½-2¼	6.7	6.7
2¾-⅜	2.5	4 -½	4.2	8¾-2¼	7.5	7.5
3 -⅜	2.7	4¼-½	4.7	9 -2¼	8.3	8.3
3¼-⅜	3.0	4½-½	5.2	9¼-2½	9.2	9.3
3½-⅜	3.3	4¾-½	5.7	10 -2¾	10.0	10.0

It is advisable to use a larger factor of safety with flat rope than with round rope of equal strength, so that the proportion between their weight for equivalent working strength is about as 7 to 5 in favor of round rope. The following formula, for proportionate dimensions of flat-rope hoisting drums, is one that practice has approved: $D = (12\,d - 3.15\,R^2\,t) + 37.7\,R$, in which $D =$ the diameter of the drum in feet, $d =$ the depth of the shaft in feet, $R =$ the number of revolutions of the drum in descending, and $t =$ the thickness of the rope in inches.

Wire Rope for Ships' Cables.—The use of wire rope in marine service is being constantly extended. The advantages are evident from inspection of the following table, showing the comparative dimensions and weight of wire rope, hemp rope, and iron chain cables:

Table showing Ropes and Chains of Equal Strength.

SIZES, IN INCHES, FOR EQUAL STRENGTH.				AVERAGE WEIGHT PER FOOT.				Working Strain.
Crucible Steel Rope.	Charcoal Iron Rope.	Hemp Rope.	Iron Chain.	Steel Rope.	Iron Rope.	Hemp Rope.	Iron Chain.	
Cir.	Cir.	Cir.	Dia.	Lbs.	Lbs.	Lbs.	Lbs.	Tons.
....	1.09	2¾	7/32	....	0.14	0.34	0.50	0.3
....	1.18	3	¼	....	0.21	0.46	0.65	0.4
1.09	1.39	3¼	9/32	0.17	0.28	0.67	0.81	0.5
1.26	1.57	4¼	5/16	0.25	0.33	0.75	0.96	0.6
1.43	1.77	4¾	⅜	0.30	0.45	0.93	1.33	0.8
1.57	1.97	5	7/16	0.35	0.57	1.16	1.76	1.0
1.77	2.19	5½	15/32	0.45	0.70	1.20	2.20	1.3
1.96	2.36	5¾	½	0.59	0.88	1.60	2.68	1.5
2.36	2.75	6½	9/16	0.85	1.03	2.00	4.21	2.3
2.75	3.14	7½	19/32	1.10	1.43	2.65	4.88	3.1
2.95	3.58	8½	⅝	1.29	1.80	3.35	5.75	3.9
3.14	3.93	9½	¾	1.45	2.39	4.00	7.50	4.3
3.53	4.32	10½	13/16	1.88	2.94	4.92	9.93	5.9
3.93	4.71	11½	1 1/16	2.33	3.56	5.83	10.6	7.0
4.32	5.10	12½	1⅛	2.98	4.00	6.20	11.9	8.2
4.71	5.50	14½	1¼	3.58	4.89	8.70	14.5	9.5
4.81	5.89	15½	1⅜	3.65	5.60	9.00	17.6	11.0
5.10	6.23	16½	1⅜	4.04	6.30	10.1	20.0	12.5
5.89	7.07	17½	1½	5.05	7.95	13.7	22.3	15.9
6.35	7.85	18½	1⅝	6.50	9.81	16.4	24.8	19.6

Wire rope is now extensively used for the standing rope in ships' rigging, having been adopted by the United States Navy Department, after thorough tests, in 1868. More recently attention has been given to the advisability of its use for hawsers and anchor-cables. Experiments recently completed by the English Government have been largely in favor of its adoption upon large vessels. According to official report, the saving in weight would be as the following figures indicate: The 25-inch hemp rope in use weighed 7.8 tons; 2¼-inch (diameter) equivalent chain cables would weigh 16 tons; 8-inch equivalent steel-wire rope would weigh 2.5 tons. The report was also largely in favor of wire rope as to ease in handling. The cost of the three is about in the proportion of 38 for wire rope, 85 for hemp rope, and 80 for iron chain cables. The objection has been raised against its use for anchor-cables, because of the rapid corrosive action of salt water upon it. By the use of galvanized wire rope, and by a proper protective coating, and care in stowing away after using, this may be reduced to a very small item, which the large balance to its favor in first cost and weight more than compensates. When not galvanized, wire rope is protected by coating it with raw linseed oil, or with a paint composed of the oil with Venetian red.

Material for Wire Rope.—The best material for wire rope depends in a measure on the use it is to be subjected to. In general, however, a tough, pliant material is better than one of high tensile strength alone. In rope for hoisting purposes, where it is subject to shocks or sudden strains, and where the factor of safety is large, this is particularly the case. The same is also true for rope used in transmitting power. For standing rope and tramways this is not so imperative.

For suspension bridges, the best material should be used, combining the highest degree of both qualities; but, because of the repeated shocks and vibrations the cable is subject to, it is safer to lean in the direction of toughness and elasticity than toward that of high tensile strength alone. The specifications for the steel wire composing the great cables of the "East River Suspension Bridge" required a wire with a tensile strength equivalent to 160,000 lbs. per square inch, with a modulus of elasticity between the limits of 27,000,000 and 29,000,000, an ultimate elongation at breaking of 3½ per cent. in foot-length tests, and with a diminution at the point of fracture equal to about 8 per cent. of its diameter. The strength per square inch of wire section laid in place in the rope is stated to be about as follows: Crucible cast steel, from 100,000 to 120,000 lbs.; Bessemer steel, from 93,000 to 107,000 lbs.; iron, from 70,000 to 80,000 lbs.; galvanized charcoal iron, from 72,000 to 75,000 lbs. The strength per square inch of rope section is about 58 per cent. of an equal section of solid metal of the same tensile strength per square inch.

The foregoing is abridged from a pamphlet on "The Manufacture of Wire Rope," written by Mr. J. B. Stone, C. E., 1879. For transmission of power by wire rope, see BELTS; for wire-rope towage on canals, see CANALS; for wire-rope propulsion on street railroads, see RAILROADS, STREET; for wire-rope submarine cables, see TELEGRAPH.

WOOL MACHINERY. The various operations of the woolen manufacture are as follows: The material is first sorted with reference to its weight, softness, fineness, strength, color, and cleanness, and the various qualities are separated in order to avoid unevenness in the working and in the fabric. The technical terms for the various kinds of wool are as follows: The first and finest quality is called *picklocks*; second, *prime*; third, *choice*; fourth, *super*. These are wools of the best kinds; while the remainder are inferior, and have the following designations: fifth, *head-wool*, or the chief of the inferior division; sixth, *downrights*; seventh, *seconds*, which is that grown on the throat and breast; eighth, an inferior kind to the last, called *abb*; ninth, *livery*, the long coarse wool about the belly; and tenth, *short coarse*, from the breast of the animal.

Scouring follows in washing machines, the object being to remove suint and grease. Alkaline water is first used, and then clear water. The wool then passes to the drying machine, where it is subjected to a blast of dry air, either hot or cold; and thence it is taken to the willowing or dusting machine, in which teeth, fixed on revolving cylinders, disentangle the locks, while a blast of air from a fan removes the dust and drives the wool through in a flocculent state. Most wool contains *burrs* (seed-vessels of plants), which become attached to the sheep while grazing; these are removed by a burring and picking machine, which is also often constructed to extract dust and other impurities at the same time. In order to prevent felting of the fibres during subsequent operations, the wool is oiled with some thin, clear vegetable oil, such as olive, rape, cotton-seed, etc. An ingenious oiling apparatus, constructed by Messrs. Charles G. Sargent's Sons of Graniteville, Mass., precipitates the oil in a finely atomized state upon the evenly-spread wool as it passes the feeding rolls of the carding engine. Usually the oil is mingled with water, the proportions for the above machine being about one part of oil to four of water, and the quantity of oil applied varying from one quart to ten quarts per 100 lbs. of wool, to suit the work in progress.

Scribbling is a preliminary carding in order to disentangle the fibres. The regular carding operations which follow leave the wool in the shape of fleece, slivers, rolls, or rovings, as the case may be The drawing and spinning processes are not materially different from those used in cotton-cloth manufacture. Weaving woolen goods is described under LOOMS; and the various finishing operations are detailed under CLOTH-FINISHING MACHINERY and FULLING MACHINES.

The manufacture of felted cloth from wool has been brought to such perfection, that for many purposes the cloth rivals woven fabrics in utility. The washed and cleaned wool is first carded, and thus transformed into a sliver several feet broad, but not much thicker than a cobweb; and this is received and wound on a roller, until a sufficent length has been obtained. Then a number of these rollers are placed in another machine, in which they are made to unwind the slivers and deposit them one over another, until a lap of the required thickness is formed, this being often an inch, necessitating a great number of slivers. This lap is then made to pass through a series of wooden and tin rollers, arranged so that the upper rollers of wood are partly between the pairs of the lower tin rollers. The upper ones are of solid wood, the lower of tin, hollow and filled with steam, and all placed in a long, shallow, but broad trough of hot water. The lower rollers simply revolve on their

6303.

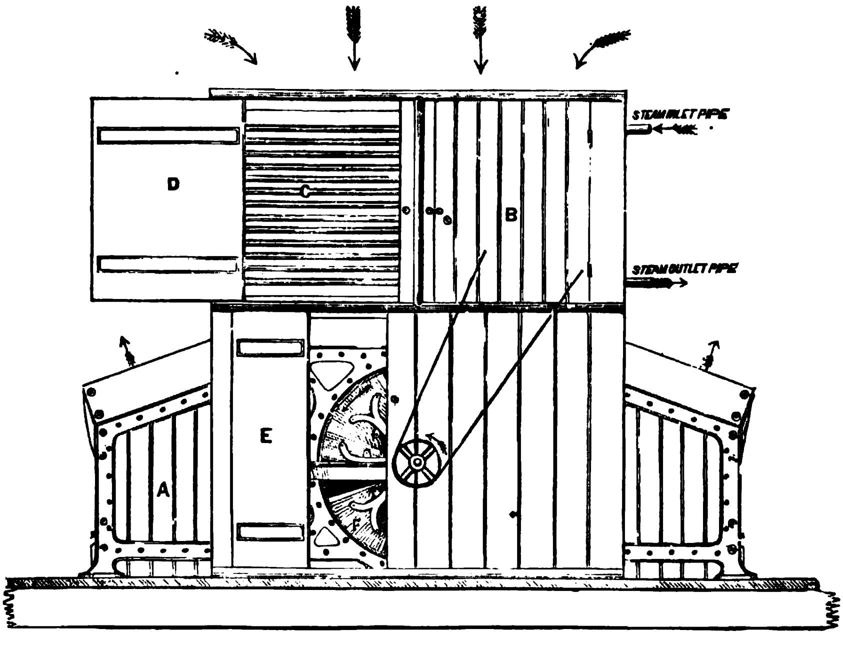
SARGENT'S WOOL-WASHING MACHINE.

axes, but the wooden ones, besides this motion, have a slight movement from side to side, which causes them to rub the lap of slivers, and induces the fibres of wool to combine and felt together as they are carried along by the revolutions of the two sets of rollers, the heated water greatly helping in the operation. In the end, what went in as a thick sheet of wool, like wadding, comes out a compact thin cloth, in some instances as fine in appearance as a kerseymere, which, after being dyed or printed, is tentered and pressed, and is then ready for sale. This process admits of very inferior wools, and the noils of wool or even of flax, being mixed and made into low-class cloths for druggets and other coarse fabrics.

The manufacture of wool hats is described under HAT-MAKING MACHINERY. The principal machines used in the woolen manufacture are detailed hereafter.

The Wool-washing Machine.—The first machine used in the process of the woolen manufacture is the wool-washing machine. An example of this apparatus, as made by Messrs. C. G. Sargent's Sons, Graniteville, Mass., is represented in Fig. 4309. This machine consists of a series of stationary rakes, or racks, alternating with movable ones, which are actuated by a crank-motion, and arranged in a long box partially filled with scouring liquor. The wool is placed on the feed-apron, which carries it forward, and drops it into the box back of the first stationary rake. The rakes are suspended on pivots at each end and allowed to swing a short distance freely. The wool remains behind this stationary rake until the first moving rake comes forward, passes its teeth between the teeth of the stationary rake first mentioned, seizes a portion of the wool, and carries it forward to the action of the second rake. By the time the wool has arrived at the fourth rake (if that number is used), it has become thoroughly saturated with the liquor, the dirt, grease, and all foreign matter loosened ready for removal by the squeezing rolls. It remains to conduct the wool out from the liquor. By means of the last rake in the bowl the wool is carried upon the convex table and left, where it is held by a series of projecting teeth fixed in the face or top of said convex table, until the backward movement of the rake, which is connected by a connecting-rod to the swing-carrier, draws said carrier back, and, by means of the link-connection with the rear end of the carrier, lifts said lower or rear end of said carrier and teeth up, and passes it down over the wool on the convex table, ready for the return movement, which carries the wool up to the squeeze-rolls; the teeth in the carrier—being jointed, and free to swing upward in its backward movement—lift and slide over the wool without disturbing the same; when the motion is changed the teeth fall back against a stop, which holds them in a perpendicular position, so that in their upward passage they sweep and carry all the fibre upward to the squeeze-rolls, as before described. The advantage of this is that the wool is carried to the squeeze-rolls in an evenly distributed mass like a web. The more evenly the wool is delivered to the squeeze-rolls, the more perfectly the water is extracted or squeezed out. When more than one box or "bowl" is used, the liquor in the first box soon becomes dirty and is drawn off, and the liquor from the second box is forced back into its place by means of an injector attached to the side of the machine, and the second box is filled up with fresh liquor.

4310.



Wool-Drier.—From the washing machine the wool is taken to the "drier," shown in Fig. 4310, which can be used either as a hot- or cold-air drier by reversing the direction of the fan. The fan, being put in motion, sucks the air down through the top of the air-box (which is open), passes the

steam-pipes, and is heated in its passage to the fan, which forces it forward into the drier under the wire netting supporting the wool. The pressure of the air forces it up through the wool, and in its passage absorbs the moisture contained in the fibre. The air-box and coil can be placed under the floor, and take the air from the room below, if more convenient. In warm, dry weather, the steam can be shut off from the coil, and simply cold air used, or sufficient steam admitted to do the amount of work required.

The various parts are as follows: *A*, end view of drier-frame; *B*, air-box; *C*, coil of steam-pipe in the air-box; *D*, door that opens into the air-box for the purpose of examining the pipes, etc.; *E*, doors in the air-box opening into the fan, for oiling, etc.

Wool-Picking and -Burring.—From the drier the wool is taken to the wool-picker, which is a very simple machine, consisting of a pair of feed-rolls, which deliver the wool to the action of a toothed cylinder, or set of beaters armed with steel teeth, and supported at the end of radial arms attached

4311.

to a central shaft. This cylinder or beater is usually 36 in. in diameter and from 30 to 36 in. wide, and revolves from 500 to 700 times per minute, detaching the fibres of the wool from the clotted masses in which they are left by the washer, and preparing them for the card. Where wools containing many burrs are used, the form of picker represented in Fig. 4311 is used, as built by Messrs. C. G. Sargent's Sons of Graniteville, Mass. In this machine, the wool taken from the feed-rolls by the picker-cylinder is carried by it to the burr-cylinder, which is composed of a series of circular saws, very similar to those of the cotton-gin, bolted together on an axle, and separated from each other by thin washers, which admit of the entrance of the wool between the saws, but not of that of burrs or other foreign substances. This cylinder is sometimes formed by winding a saw-toothed wire, with a flange on the edge opposite to the saws, in a spiral direction around a solid cord, instead of using circular plates. The wool, which is received by this from the picker-cylinder, is carried round with it, passing between the teeth of the saw, while the burrs and other foreign matters adhering to the wool are knocked off by a revolving beater, the blades of which just clear the teeth of the saws, as shown at *H* and *I*. A revolving brush and fan clears the wool from the teeth of the burr-cylinder and delivers it to the wool-burr, in readiness for the card.

The parts of this machine are as follows: In Fig. 4311, *A* is a side view of the perforated screen; *B* shows the back girt of the screen, seen in section in Fig. 4312; *C* indicates the front girt of the screen. *D*, Fig. 4312, also shows the screen. *E* shows the front girt and register of screen *A*. This

register, or air-passages, can be opened or closed by a slide which regulates the draught under the burr-cylinder *H* and guard *I*. *F* shows the picking cylinder, which takes the wool from the feed-rolls *L* and *M* and carries it forward, combing it into the burring cylinder *H*. *G* shows the rack under the picking cylinder *F*. *H* is the burr-cylinder, on which the burrs are separated from the wool by the guard *I*, the burrs dropping through the fingers of rack *K*. *J* is the brush which keeps the burr-cylinder constantly clear, moving all cleansed wool, passing it out from the machine through spout *R* as indicated by arrows. *K* is an adjustable rack, of which a front view is seen in section in Fig. 4313, removed from the machine. *L* indicates the top feed-roll, and *M* the bottom feed-roll, both of which are filled with cockspur teeth. *N* shows the apron-roll. *O* represents the feed-apron, which carries the wool into the feed-rolls. *P* indicates the fan, which sucks off all light impurities, dust, etc., liberated from the wool being cleansed by the currents of air passing under the feed-rolls *L* and *M*, and under the guard *I*, up through screen *A* into the fan, as shown by arrows. *Q* shows the pipe through which the light dust is carried out.

Wool-Carding.—The wool-cards shown in Figs. 4315 and 4316 are fair types of the form of machines in common use in the United States, and are taken from drawings furnished by the makers, Messrs. Davis & Furber of North Andover, Mass. The wool is weighed out by the tender, and spread on the feed-apron *A*, from which it passes between a pair of feed-rolls at *B*, and is delivered by a "licker-in" to the main cylinder *C*, from which it is lifted by the strippers *D*, and passed to the "workers" *E*, by which it is again returned to the main cylinder. It is then loosened from the cylinder by the "fancy-roll" *F*, which is clothed with long straight teeth, and is finally taken from the cylinder by the doffer *G*, from which it is in turn removed by the doffing comb *H*, and passes through the drawing rolls *I I*, to be wound into a roving or sliver on the balling roll *J*. This rov-

4315

ing or sliver is then transferred to the second breaker-card in some cases, and in some directly to the finisher, either by setting up a sufficient number of spools or bobbins of the roping to fill the width of the card, or, by what is known as the "Apperly feed," delivered continuously by a diagonal motion to the feed-apron, so as to form a continuous lap. A traveling tube or trumpet receives the sliver as delivered from the first card, and is traversed by a screw forward and back along a slide-rod in a diagonal direction to the feed-apron, carrying the roving with it, and distributing it so as to form a sheet upon the apron. A spring-catch at either end of the slide holds down the roving as delivered, till it is taken up by the feed-rolls, which deliver it to the card-cylinder as before. The operation of the second breaker and finisher cards is the same as that of the first breaker; but the doffing is very different, there being two doffing cylinders as seen in Fig. 4316, with narrow strips of card-clothing so arranged upon them as to receive the wool from alternate zones on the main cylinder. The narrow strip of wool-sliver or roving thus received is taken from the doffer by the rotation of a roller covered with leather, seen at *C* in Fig. 4315. An under roller geared to and revolving with this carries the roving forward to a second pair of "rubbers," so called, and these deliver it to another pair. Each of these pairs of rubbers receives a vibratory motion in the direction of its axle, from a crank-shaft at the opposite end of the frame from that shown, acting in opposite directions on the top and bottom rollers of the pair, so as to condense and roll the loose sliver into a spongy roving, in which form it is received upon the spools and taken to the spinning jack or mule.

Metallic waste-cards are used for working or reducing yarn, thread-waste, and soft flannels to wool. These machines in principle are a carding machine, clothed with strong, sharp-pointed, steel

4316.

DAVIS & FURBER'S WOOL-CARDING MACHINE.

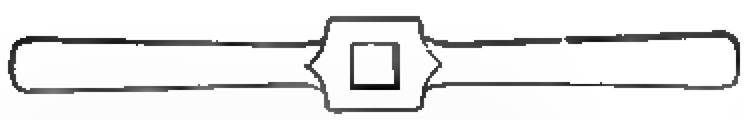
teeth, so adjusted as to work on the twist of yarn or thread-waste, combing or teaseling out gradually the twist holding the fibre of wool together, and forming it into a thread. This gradual removing of the twist, by the combing or carding process, leaves the fibres of wool composing the thread-waste long and strong, with nearly the original length of staple.

The Woolen-Mule.—The operation of this machine is very similar to that of the cotton-mule, except that the delivery of the roving is not continued for the whole length of time occupied by the carriage in "drawing out," the motion of the feed-rolls being arrested before the carriage has completed its stretch. By this action the yarn is made more even, as the twist, which at first tends to run into the finer parts of the roving, and which is continued during the whole length of the draught, also holds these parts from yielding when the delivery from the rollers is stopped, and permits of the stretch of the coarser and more spongy portions, which, as they are reduced and elongated, also take up their proper share of the twist. The other motions are very similar to those of the cotton-mule.

Wool-warping Machine.—The preparation of woolen yarns for weaving differs from that of cotton yarns. Fig. 4317 represents the wool-warping machine built by Messrs. Davis & Furber of North Andover, Mass. The yarn is first wound on spools *A*, which are placed in a proper frame or "creel" in such number as may be needed to form a section of the warp, and the yarn is taken from them through the size-rolls *B*, dried over the copper cylinders *C*, and wound upon the reel *D*. This reel is mounted in a frame, which travels longitudinally on a railway *E*, fixed in the floor so that when one section is filled the reel can be moved so as to bring another division opposite to the centre of the dresser. This plan affords great facilities for preparing the particolored warps so common in woolen goods, and admits of the repetition of the necessary pattern for shawls, plaid, cassimeres, etc., until the reel is filled to the width necessary for the goods to be produced. After the reel is filled, the belt connecting it with the dresser is removed, and yarn is transferred from it on to the loom-beam in a continuous sheet. S. W. (in part).

WRENCH. A tool used by hand to turn or rotate other tools, nuts, or bolts. A solid wrench is formed of a single piece of metal, having a notch or opening of suitable shape and size to fit on the objects to be grasped. It is specifically designated according to the shape of the recess or aperture as a square wrench, hexagon wrench, etc. If the opening is at one end, it is termed a single-ended wrench; if it is in the middle, a double-ended wrench. If the recess is open, it is termed an open-ended wrench; if closed, forming an aperture through the metal, a box-wrench. A solid wrench

4318.

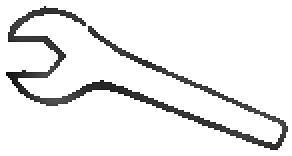


4319.

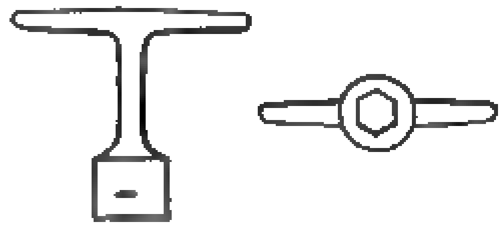
having an angular recess notched on its sides, so that any nut or bolt which will enter the jaws can be grasped, is called an alligator wrench, and is one of the most convenient forms. To illustrate, Fig. 4318 is a double-ended square wrench; Fig. 4319, a single-ended square wrench; Fig. 4320,

an open-ended wrench, sometimes termed a "spanner;" Fig. 4321, a box hexagon wrench, shown in two views. Ratchet-wrenches, used for turning drills, are described under DRILLS, METAL-BORING.

4320.



4321.



Screw or monkey wrenches are those which have a movable jaw, so that the tool may be adjusted to fit any sized nut within its compass. An immense number of such wrenches have been devised.

4322.

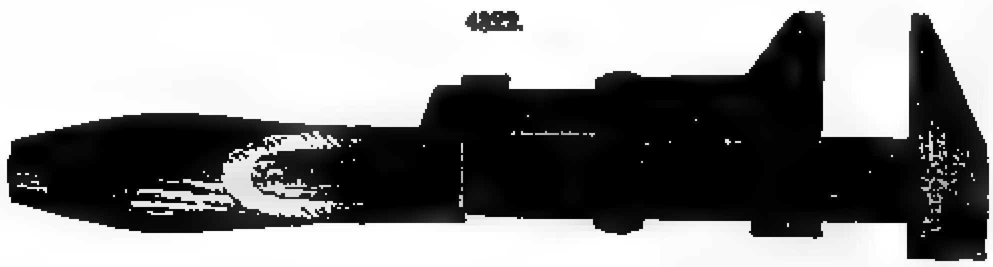
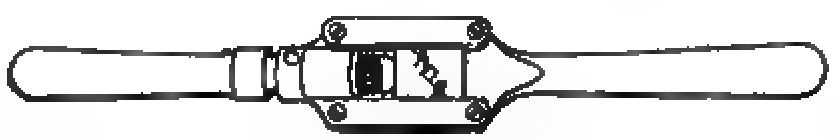


Fig. 4322 represents one of improved form manufactured by Messrs. L. Coes & Co. of Worcester, Mass., which will serve as an example of the class. The construction of this wrench, which is

4323.



simple and strong, will readily be understood from the engraving, parts being broken away to show the connection between the screw and jaw, and the method of firmly securing the shank in the

4324.

handle. The rotation of the screw by the milled cylinder shown causes the movement of the jaw along the shank.

Fig. 4323 represents a tap-wrench, for holding taps (see SCREW-CUTTING TAPS AND DIES) during

the cutting of inside threads. The jaws A and B have rectangular notches, which unite to form a square opening, which may be enlarged, while always retaining its shape, by the movement of the

adjusting screw shown. Fig. 4324 is another form of tap-wrench, made by the Wiley & Russell Manufacturing Company, in which the tool may be quickly adjusted and secured by the collar shown.

Fig. 4325 is a wrench made by the above-named firm, and especially constructed for taking off and putting on nuts in places difficult of access, such as on tire-bolts inside of carriage-felloes.

Fig. 4326 represents an improved form of combination wrench manufactured by the Bemis & Call Company of Springfield, Mass. The lower jaw is operated by a screw, and the device is adapted to grasp either nuts or pipes.

WRINGING MACHINE. See Laundry Machinery

WRITING MACHINE. See Type-Writer.

ZINC FURNACE. See Furnaces, Metallurgical.

INDEX.

Titles of Articles are distinguished by being in Italics.

END OF VOLUME II.